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THE PRE-DETERMINATION OF DYNAMO CHARACTERISTICS.

THE Society of Telegraph Engineers is to be congratulated on having opened its session with a paper of great importance, and English electricians, still more than they have already been justified in doing, may regard with satisfaction the undoubted fact that, although this country cannot claim to have taken the first important steps from which the modern dynamo, by a singularly rapid growth and evolution, has resulted, it has completely vindicated its scientific reputation by leading the van in the subsequent development and improvement of the dynamo, both theoretically and practically. Mr. Kapp's paper, to which we refer, seems to go a long way in the direction in which progress has become especially desirable—the pre-determination of the characteristics of dynamos. Much has been done within the last few years to render the task of designing dynamos comparatively easy, but the work has been for the most part carried out by practical constructors in their efforts to improve their particular machines, and there has been a want of definite comparative *data* of a numerical character such as is absolutely necessary to foretell with even an approach to accuracy the manner in which a new machine will act. This reproach to electrical science is being gradually but surely removed, and we may confidently expect that in the course of a year or two it will be quite possible to tell not only how best practically to proportion a dynamo or motor in all its parts, but to state in definite and exact terms and units the proper dimensions and qualities of each part; and having done this to state with precision the behaviour of the machine under any given conditions. Mr. Kapp's paper deals with the construction, beforehand, of what we may call the "idle" characteristic curve of dynamos. The curve of magnetisation constructed by the method dealt with is in no essential respect different from the ordinary "characteristic" with which we are more familiar, and which exhibits the connection between the speed of a dynamo and its E.M.F. This curve and the relation which it expresses, although claimed on the other side of the Channel by M. Deprez, was, we believe, first studied by Dr. John Hopkinson.*

We have no doubt that before long we shall be able to fully construct, by pre-determination, the full "working" characteristic of dynamos, or the curve displayed by machines when generating current. At present we may well be satisfied to have a good working theory for the construction of the "idle" characteristic or curve of magnetisation, especially as in good dynamos the effect of induction by the armature current is comparatively small, and is likely to decrease as further improvements are made. It is perhaps a little singular that the more we know about magnetism the more we see that the analogy between the electric circuit and the magnetic circuit is in reality a very close one, and that the methods which enable us to pre-determine the flow of a current of electricity in a circuit when we know the E.M.F. present and the character of the various bodies which constitute the circuit, will, with equal certainty, enable us to pre-determine the flow—if the word, for the sake of the analogy, may be allowed—of magnetic "lines of force" in the region influenced by the presence of a magnet. We are able to say with perfect truth that Ohm's law applies equally to the two cases. The analogy is incomplete only in one respect, viz., that while, at any rate for a metallic conductor, the resistance is a constant quantity—assuming its temperature to remain constant—for any density of current, the magnetic resistance of iron varies with the density of the lines of force. It is in dealing with this question of the increase of the magnetic resistance of iron, within working limits, that one of the principal points in Mr. Kapp's paper is to be found; for he shows that by the use of a tangent function we can determine the increase of magnetic resistance in such a way as to accord with experiment.

We trust that in the discussion of this paper, the question of the resistance of the air with special reference to leakage of lines of force may receive very careful attention. Prof. Ayrton, in his remarks on this point, stated his belief that even for low degrees of magnetisation, the resistance of the air is less than has usually been assumed in comparison with that of iron, and as on this resistance depends to a certain extent the proper ratio to be observed between the sectional area of field magnets and that of armature cores, too much attention can scarcely be given to it. If this resistance is low, then it follows that large pole-pieces, protruding a considerable distance from the magnetising coils, such as are used in Mr. Kapp's own dynamo, are objectionable. A fortnight ago we published a paper by M. Marcel Deprez from *Comptes Rendus** on this very subject, and although in some of his claims of priority he is, as is not unusual, a little late in the day, the paper should receive careful attention in connection with the subject under discussion. Mr. Kapp assumes that, as regards air, the magnetic resistance is analogous to electrical resistance, being simply proportional to the ratio of length divided by area. M. Marcel Deprez, in the paper alluded to, while he does not exactly say that this relation is incorrect, affirms that the intensity of a field decreases much less rapidly than the distance of the pole-pieces increases. He makes what appears to us to be a contradictory distinction between a field, the poles of which are separated simply by air, and one in which an iron armature is comprised; and describes, or rather alludes to, some experiments which are equally con-

* See ELECTRICAL REVIEW, Vol. VII. p. 167 (May 15th, 1879), Vol. VII. p. 167 (May 25th, 1880).

* ELECTRICAL REVIEW, November 5th, p. 448.

tradictory. In one case the intensity of the field existing between the two poles of an electro-magnet was only reduced by one-half when the air space was increased ten-fold. In another case the intensity of the field maintained between the pole-pieces and an iron armature was more slowly decreased, falling from 1 to 0·6 for a four-fold increase of clearance. In the absence of full particulars it is impossible to attempt to criticise these statements, but it certainly appears on the surface as if M. Deprez had been experimenting with electro-magnets, the cores of which were so highly saturated as to offer a considerable resistance in themselves.

There is one statement in this paper of M. Deprez's to which we venture to allude, as it involves a question of priority of invention or discovery, or at any rate of application, which we are now in a position to settle, thanks to the letter of Messrs. Mather & Platt, published in our last issue. M. Deprez, in the article alluded to, says:—"I was the first to construct very thick and short electro-magnets (experiments in the depôt of the Northern of France Railway in February, 1883), instead of employing electro-magnets of small diameter, long and numerous, as was done in the Edison machine which figured at the exhibition of 1881. My example has been followed with full success, and the magnetic field of the Edison machines since constructed has been considerably improved simply by decreasing the length of the electro-magnets and thickening the core."

We quote the passage in its entirety, because it is desirable that M. Deprez should be allowed to state his own case. We, in England, have been in the habit of connecting the improvement of the Edison dynamo with the name of Dr. Hopkinson, and, as we now know, with perfect justice. For it appears from the letter of Messrs. Mather & Platt, that as early as the autumn of 1882 Dr. Hopkinson first experimentally demonstrated the advantages of the altered form of the magnetic circuit of the Edison dynamo; that early in December of the same year he gave instructions for a dynamo on the improved lines which was constructed and tested with most satisfactory results early in January, 1883; and that machines involving the improvement were actually delivered for commercial use in the following March. Our readers will doubtless recollect that this matter was first given public prominence by Dr. Hopkinson in a lecture at the Institution of Civil Engineers on April 5th, 1883,* at which time M. Deprez had not, so far as we are aware, made any announcement on the subject. We therefore see that the example which M. Deprez correctly says "has been followed with full success" is certainly not that of M. Deprez; although we are quite willing to allow him the degree of merit to which, according to his own statement, he is fully entitled, namely, that he was only a few months behind Dr. Hopkinson in this matter. And this is no slight honour, and one with which others than M. Deprez must make shift to be satisfied.

* ELECTRICAL REVIEW, Vol. XII., p. 302.

But whatever may be the case with regard to the magnetic circuit of the dynamo, we need not remind those of our readers who have not lost all interest in the less bulky electrical apparatus, that the substitution of short thick magnets for long thin ones is an improvement which was made in telegraphy a good many years ago. Who does not remember the long and slender legs of the Morse "embosser," and all its kin, with their tight-fitting trowsers of green silk-covered wire; or who can forget the respect inspired by the appearance—some 12 years ago—of the sturdy little electro-magnets which replaced them, and which owed their exceeding vigour to the very improvement which M. Deprez with so little justification is now claiming as his own?

But we are wandering from our subject, to which we will return only for a moment to say that we hope the claims of the "practical" workers will not be forgotten amidst the din of contending mathematicians. Mr. Crompton, speaking on Mr. Kapp's paper, put in a timely word for those who, although perhaps incapable of integrating a curve to zero, are possessed of what he calls "an eye," and who have been able, by the unaided assistance of that useful organ, to carry out exceedingly useful improvements.

But our readers will be aware, from the paper on "Dynamo-Electric Machinery," by Dr. John Hopkinson and Dr. Edward Hopkinson, which we are reproducing from the *Philosophical Transactions* of the Royal Society, that the questions dealt with by Mr. Kapp, and other questions connected with the dynamo, have been very fully dealt with some months ago. It is much to be regretted that owing to the manner in which the Royal Society fails entirely to appreciate the value of time in matters of modern science, especially in science which has an immediate bearing on industrial progress, the invaluable paper by the Drs. Hopkinson, which was read in May last, is only now available for study. We cannot now do more than allude briefly to this paper, in which will be found not only many theoretical considerations bearing on the "pre-determination of dynamo characteristics," but also many practical experiments of an exceedingly interesting and important character. For instance, the ratio of the total induction to the induction in the armature was determined experimentally, and it was found that for an Edison-Hopkinson dynamo, of the total lines of force passing through the cores of the magnet limbs at the centre, $\frac{200}{264}$ go through the core of the armature. Again, the routes by which the waste lines of force were lost were examined, and the losses in the various directions are expressed as percentages.

As the authors express it, these investigations appear to "tell the whole story of a dynamo machine," and we may safely anticipate, as a result, a considerable practical improvement in such machines all along the line.

One interesting consideration we may allude to in conclusion. It is shown that in a generator it would be possible, but for the sparking which would ensue, by making the angle of lead negative, to thereby obtain, by the reactions of the armature itself, all the results usually obtained by compound-winding.

ELECTRIC MOTORS IN AMERICA.

(*Continued from page* 430.)

For a properly constructed motor the field magnet must at no time be too highly saturated, that is, it must be worked with a characteristic which is a straight or very nearly a straight line.

Let f denote the resistance of the main or shunt field coils; m the number of turns therein; r the resistance of the differential or series field coils, and n the number of turns; E, the difference of potential at the shunt terminals; e the counter electromotive force set up in the armature; and R the resistance of the armature

The work done $= e\,\frac{E - e}{r}$; that is, it depends upon e, a variable quantity, and upon the constants E and r.

Now e varies with the speed and field, or the effective magnetic moment of the field, but the conditions are that the speed remains constant, hence e must vary with the field alone.

$$\text{Current in shunt field} = \frac{E}{f}$$

$$\text{Magnetic moment of same} = m\,\frac{E}{f}$$

$$\text{Current in series field} = \frac{E - e}{R + r}$$

$$\text{Magnetic moment of same} = n\,\frac{E - e}{R + r}$$

The effective magnetic moment must then be $m\,\frac{E}{f} - n\,\frac{E - e}{R + r}$: and the conditions are such that (for two different counter electromotive forces or two different loads)

$$\frac{e}{e^1} = \frac{m\,\frac{E}{f} - n\,\frac{E - e}{R + r}}{m\,\frac{E}{f} - n\,\frac{E - e^1}{R + r}}$$

or

$$\frac{e}{e^1} = \frac{m\,E\,(R + r) - n\,f\,(E - e)}{m\,E\,(R + r) - n\,f\,(E - e^1)}$$

or

$$\frac{e}{e^1} = \frac{m\,E\,(R + r) - n\,f\,E + n\,e\,f}{m\,E\,(R + r) - n\,f\,E + n\,e^1 f}$$

or

$$e\,m\,E\,(R + r) - e\,n\,f\,E + e\,n\,e^1 f = e^1\,m\,E\,(R + r) - e^1\,n\,f\,E + e^1\,n\,e\,f.$$

Cancelling we have

$$e\,m\,(R + r) - e\,n\,f = e^1\,m\,(R + r) - e^1\,n\,f,$$

or

$$m\,(R + r)\,(e - e^1) = n\,f\,(e - e^1)$$

or

$$\frac{m}{n} = \frac{f}{R + r}$$

That is to say, the number of turns in the shunt coil must bear the same ratio to the number in the series coil as the resistance of the shunt coil bears to the sum of the resistance of the series coil and the armature.

This is the Sprague law of winding for a machine of the kind mentioned, and so wound it will be self-regulating for any constant potential up to the maximum allowed by the construction of the machine, and from no load up to the maximum.

There is a feature of motors so wound which may be here noticed: the ratio of the initial to the effective electromotive force is the same as the ratio of the moments of the shunt and series coil.

When $e = 0$ this ratio becomes $\frac{E}{E} = 1$; that is, the moments are equal, and this means that, in a perfect machine, if both coils be closed and in their normal position, for any potential or current, a zero field, or practically so, will be formed, and the motor will either not start at all or if it does start will run at a very great speed, take the maximum current at any given potential and do little or no work at all.

How to obviate the bad effects of this peculiarity, yet to take advantage of it, will be shown later.

What has already been pointed out may be again stated, that the motor will regulate itself perfectly for all potentials so long as we work with a straight line characteristic, but it must be with a theoretical efficiency of not less than 50 per cent., for if we go below this, the governing coil works in the wrong direction.

Referring to the equation $\frac{m}{n} = \frac{f}{R + r}$, it will be seen that m and n can be increased in the same ratio. That is, if means are provided for varying the effective magnetic moments of shunt and series coils the motor can be set to run at different determined speeds. It is evident that f and r can also be varied to change the speed.

We need not give the full mathematical analysis of the conditions found when a differential motor is placed on a constant current circuit. Both series and shunt, and series and "long shunt" windings are considered, and it is shown that there is little chance of such motors being used on constant current circuits where self regulation of speed is required, for from the analysis it follows that a motor of either class depending for its regulation on this differential winding will regulate with a constant current only when working at less than 50 per cent armature efficiency; and that the same machine with the same winding will regulate on a constant potential circuit only when working at over 50 per cent. armature efficiency.

The fact already pointed out, that in the best self-regulating motor there is a zero or very weak field when the motor is started, necessitates, especially when it is desired to start at a speed not greater than the normal, or when there is any load on the motor, in which case there is danger of burning out, the use of devices whereby the action of the governing coil may be modified.

This may be done by the introduction of a resistance, by shunting the coil with a resistance or by the variable shunting of the armature upon the main field. Mr. Sprague, however, prefers to use a switch to short-circuit the governing coil or to short-circuit and reverse it. If it is reversed, then the first rush of current makes a very strong field instead of reducing it to zero or nearly so, increases the rotary effort and prevents the burning out of the machine.

As an instance, if a constant potential motor has the series coil reversed when the full circuit is closed, if there is margin enough on the field characteristic we shall have a field twice as strong as the strongest normal field, four times the strength when the motor is doing its maximum work per unit of time, and a momentary rotary effort eight times that existing when the maximum work is on. As soon as the speed comes up, the governing coil is short circuited and then reversed, and then the motor is self-regulating.

Having obtained a machine which was thus automatic, Mr. Sprague made another step in overcoming the distortion, or, rather, counteracting the distortion set up by the armature, by producing a distortion in the field magnets, which is dependent on precisely the same current that flowed through the armature, and he uses two methods, of which one only will be described.

Main field magnet coils are employed in shunt relation to the armature, differential field magnet coils in series with the armature, and additional accumulative field magnet coils, also in series with the armature. The main field coils may be shunted upon the armature alone, or upon the armature and both the cumulative and differential series coils, or upon the armature and either of the series coils, the other series coil remaining outside the terminal of the main field shunt.

The object sought is to maintain the non-sparking points of the commutator cylinder constant by opposing the distortion of the magnetic field due to variations in the armature current by a counter distortion dependent upon such variations, whereby the magnetic resultant due to the armature and field magnet is unchanged, and the line of parallel cutting of the lines of force or point of least sparking is maintained in the same position.

In accomplishing the counter distortion of the field, the motor used is one in which the field magnet cores extend in different directions from the field of force in which the armature revolves. The differential series coils are wound or arranged so that their greatest effect is produced on diagonally opposite parts of the magnetic field, and the cumulative series coils, so that their greatest effect is produced on the other diagonally opposite parts. The differential coils are arranged to have a greater magnetising effect than the cumulative coils. A decrease of load, causing a decreased armature current, tends to shift the magnetic resultant of the armature and field magnet; but this also decreases the magnetising effect of all the series coils, and, therefore, the parts of the field principally affected by the cumulative coils are weakened, and those principally affected by the differential coils are strengthened, whereby a distortion of field is produced opposed to that produced by the decrease of armature current, and hence the magnetic resultant—the line of parallel cutting and the points of least sparking—remains unchanged. Thus no shifting of the commutator brushes is ever required, except on account of wear.

The arrangement of two sets of series field coils—one differential, the other cumulative—may be employed simply as a means of field regulation where it is not desired to produce the counter distortion. In such case the coils may be evenly wound on all the legs of the field magnet and used only to regulate the motor, being wound in the proportions above stated. The differential and cumulative series coils have a differential effect, which, as the differential coils predominate over the cumulative coils, produces a weakening of the total strength of the field magnet when the armature current increases, and a strengthening of the field magnet when the armature current decreases, and so maintains constant the speed of the motor.

One of Mr. Sprague's methods for varying the speed and power is to wind the field magnets with a series of coils of different cross section and resistance. These coils are all in series with each other, and the bights of the coils are brought to a commutator.

In the simplest form of this motor, one end of the armature circuit is connected with a contact arm arranged to travel over a contact range, thereby making electrical connection with different sections of the field coils. The other end of the armature circuit is connected with one end of the series of field coils, preferably at the junction of such series with the supplying circuit. As the arm moves over the successive contacts the armature is shunted around a greater or less number of the sections of the field coils, and the difference of potential between the terminals of the armature circuit is varied between the maximum and zero; but in this arrangement it is not reversed unless the connections are reversed. The contact arm is provided with an adjustable contact piece, to allow for wear. In another method, where a single set of field coils is broken up into sections, the wires from the bights are connected in a special manner to a circular range of contact pieces, and a double arm, the two parts insulated from each other and bearing on opposite sections, is used. To each of the arms is connected an end of the armature circuit, and as the arms are made to travel around the contact range the difference of potentials at the arms or the brush terminals is reduced from the maximum to zero, is then reversed, and increases; and if the arms continue in the same direction another half revolution it is diminished to zero, changed again, and increased to the original maximum. The connections of the field sections are made thus: the first and last to single and opposite blocks of the range; the next adjacent sections have double connections to the next adjacent blocks on either side of the first ones connected, the next sections to the next adjacent pairs of blocks on either side, and so on till the blocks meet. In a third method two series of field coil sections are used, and the bights connected to two ranges of contact pieces arranged in one or two circular or partly circular sets. Here, also, two arms insulated from each other are used, and the two arms are connected to the two terminals of the armature circuit—that is, the armature circuit becomes what corresponds to the galvanometer circuit in the Wheatstone bridge. As the arms are made to travel over the successive contact surfaces, the difference of potential existing at these arms or at the terminals of the armature circuit decreases from the maximum to zero, changes, and increases again to the maximum reverse potential.

In this last arrangement the speed, torque and direction of rotation can be varied as rapidly as desired without any sparking at the moment of reversal.

The standard machines are wound in the sectional method described and in addition are arranged so that when the motor is started the governing coil is in series with the armature and works accumulatively, while the potential at the armature terminals is progressively raised by moving along the field sections by means of the commutator at the top, part of the field sections being in series and the rest in shunt with the armature: this arrangement gives a very strong rotary torque—when full potential has been reached, the coarse coils are short circuited and then reversed and the machines become automatic, having the following qualities:

They can be thrown into a circuit at a dead rest, or slow speed without any disturbance of potential and consequent flickering of light. They can be started gradually, whether free or under full load, without burning of brushes or flickering of light, the potential at the brushes being raised progressively from zero to maximum. If the load is such as to prevent starting until the full difference of potential exists at the brushes, the motor then starts with a rotary effort, or torque, very much in excess of what exists under the condition of maximum work. These motors are absolutely automatic, running at nearly the same speed for all loads up to the maximum, and promptly recover their normal speed under sudden and marked changes in load. There is no change necessary in the lead of the commutator brushes.

In the larger type of machines, however, Mr. Sprague prefers to use a rheostat for throwing the machines into circuit, instead of winding the field coils in sections, because it is a much cheaper process of working, and as in case a heavy machine should be damaged in the sectional winding, it would be far more costly to make repairs to it than in the case where a rheostat is used. Of course this rheostat carries no current, except at the moment of starting.

These motors will lower a varying weight at the same speed that they will pick it up, and with the same freedom from sparking.

In another form, a variable speed machine, such as is now in use in the Western Union operating room, the rheostat is of peculiar construction. By a single movement of the switch the machine is thrown into circuit with a very strong field, the potential at the armature terminals is gradually raised, and after full potential has been reached a resistance is then thrown into the field magnet, and the field thus weakened so that the speed of the machine is increased. This method of working allows of the finest gradations of speed.

Another machine, which is just being brought out for use on constant potential circuits, permits of nine or ten variations of speed from a single switch movement without the use of any external rheostat, and another type permits of a like variation of speed and entire reversal of movement, also with the single switch. This latter type is designed for operation on street cars.

For all ordinary work motors are built for constant

potential circuits of about 100 volts. But the demand has come for 220 volt machines to go on the Edison three-wire circuits. Before long the Sprague Company expects to undertake some special cases of transmission of power in connection with mining work which involve the transmission of very large powers over long distances and under high pressure, such as 200 H.P. 16 miles with 1,000 volts at the motors, the entire electrical conditions being perfectly automatic, both at the generating and receiving end.

Among the very interesting facts which have been brought out by experience is this, that on all ordinary classes of work motors do not average over 35 to 40 per cent. of the maximum capacity which may be safely demanded of them. A central station hence can take advantage of this falling off of work, and since there is an actual recovery of about 65 per cent., and as this 65 per cent. is only about 40 per cent. of the capacity of the motors which are in operation, it follows that, for every 100 H.P. in a steam engine at a central station, including 10 per cent. loss on distribution where the work is widely distributed, about 170 H.P. can actually be contracted for. The future of the transmission of power is a bright one. There are ignorance and prejudice and other adverse circumstances to be contended against. These always enter as important factors against the success of business in any locality; but there is no class of work, even when we reckon in the larger powers, which, when dealt with on the broad plane of a central station, cannot be dealt with in the same way as the smaller powers. The public is gradually being educated to know that in every place where there is the use for machinery there are opportunities for the transmission of power by electricity. Where mining operations have to be carried on under the most expensive systems of obtaining power the field is unlimited, but where these long distances and large powers are to be used it is essential that high potentials be used, as high as a 1,000 or 2,000 volts. Mines, too, offer a fruitful opportunity both for the transportation of coal and for ventilation. In short, the universal demand for an efficient and reliable method of getting power will find its best answer in the use of electricity.

DYNAMO-ELECTRIC MACHINERY.*

By J. HOPKINSON, M.A., D.Sc., F.R.S., and E. HOPKINSON, M.A., D.Sc.

(*Continued from page* 473.)

Effect of the Current in the Armature.

The currents in the fixed coils around the magnets are not the only magnetising forces applied in a dynamo machine; the currents in the moving coils of the armature have also their effect on the resultant field. There are in general two independent variables in a dynamo machine, the current around the magnets and the current in the armature, and the relation of E.M.F. to currents is fully represented by a surface. In well-constructed machines the effect of the latter is reduced to a minimum, but it can be by no means neglected. When a section of the armature coils is commutated it must inevitably be momentarily short circuited, and if at the time of commutation the field in which the section is moving is other than feeble, a considerable current will arise in that section, accompanied by waste of power and destructive sparking. It may be well at once to give an idea of the possible magnitude of such effects. In the machine already described the mean E.M.F. in a section of the armature at a certain speed may be taken as 6 volts, its resistance 0·000995 ohm. Setting aside, then, for the moment questions of self-induction, if a section were commutated at a time when it was in a field of one-tenth part of the mean intensity of the whole field there would arise in that section, whilst short circuited by the collecting brush, a current of 600 ampères, four times the current when the section is doing its normal work. The ideal adjustment of the collecting brushes is such that during the time they short circuit the sections of the armature the magnetic forces shall just suffice to stop the current in the section, and to reverse it to the same current in the opposite direction.

Suppose the commutation occurs at an angle λ in advance of the symmetrical position between the fields, and that the total current through the armature be C, reckoned positive in the direction of the resultant E.M.F. of the machine, *i.e.*, positive when the machine is used as a generator of electricity. Taking any closed line through magnets and armature, symmetrically drawn as A B C D E F A (fig. 4), it is obvious that the line integral of magnetic force is diminished by the current in the armature included between angle λ in front and angle λ behind the plane of symmetry. If m be the number of convolutions of the armature, the value of this magnetising force is $4\pi C \frac{m}{2} \frac{2\lambda}{\pi} = 4\lambda m C$ opposed to the magnetising force of the fixed coils on the magnets. Thus, if we know the lead of the brushes and the current in the armature we are at once in a position to calculate the effect on the electromotive force of the machine. A further effect of the current in the armature is a material disturbance in the distribution of the induction over the bored face of the pole piece; the force along B C (fig. 4) is by no means equal to that along D E. Draw the closed curve B C G H B, the line integral along C G and H B is negligible. Hence the difference between force H G and B C is equal to $4\pi C \frac{m}{2} \frac{\kappa}{\pi} = 2\kappa m C$ where κ is the angle C O G.

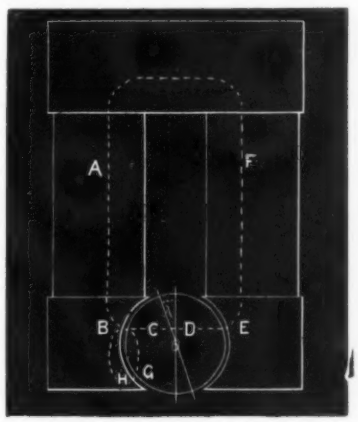


FIG. 4.

This disturbance has no material effect upon the performance of the machine. But the current in the armature also distorts the arrangement of the comparatively weak field in the gap between the pole pieces, displacing the point of zero field in the direction of rotation in a generator and opposite to the direction of rotation in a motor; and it is due to this that the non-sparking point for the brushes is displaced. A satisfactory mathematical analysis of the displacement of the field in the gap between the pole pieces by the current in the armature would be more troublesome than an *à priori* analysis of the distribution of field in this space when the magnet current is the only magnetising force. Owing to the fact that the armature is divided into a finite number of sections there is a rapid diminution of the displacement of the field during the time that a section is being commutated, the diminution being recovered whilst the brush is in contact with only one bar of the commutator. The field thus oscillates slightly, owing to the disturbance caused by reversing the direction of the current in the successive sections of the armature. The number of oscillations in a Gramme armature or in a Siemens armature with an even number of sections will be ρm, where ρ is the number of revolutions per second, but in a Siemens armature with an odd number of sections it will be $2\rho m$.* This oscillation of the field is only another way of expressing the effect of the self induction of the section, but it must be remembered that if the self induction, multiplied by change of current, is expressed as a change in the field we must omit self induction as a separate term in our electrical equations. The precise lead to be given to the brushes in order to avoid sparking in any given case depends on many circumstances—the form and extent of the pole pieces, the number of sections in the armature, and the duration of the short circuit which the brushes cause in any section of the armature. The adjustment of the position of the

* From the Philosophical Transactions of the Royal Society.

[* Added August 17th.—Armatures with an odd number of convolutions are open to one theoretical objection, which would be a practical one if the number of convolutions were very small. The $2m + 1$ convolutions constitute in themselves a closed circuit, having a resistance four times the mean actual resistance of the armature measured between the collecting brushes. When any one convolution is exactly in the middle of the field the E.M.F. of the other $2m$ convolutions exactly balance, so that there is upon the closed circuit an E.M.F. due to the single convolution somewhat in excess of $\frac{1}{m}$ th part of the actual E.M.F. of the machine. Thus there will be an alternating E.M.F. around the closed circuit of the armature capable of causing a considerable waste of power. This waste is materially checked by the self induction of the circuit.]

collecting brushes is generally made by hand at the discretion of the attendant, and is in some cases fixed once for all to suit an average condition of the machine. We shall, therefore, treat λ the lead as an independent variable, controlled by the attendant.

Let I be total induction through the armature, $I + I'$ total induction through the magnets, I' being the waste field. Let C be current in armature, c in the magnets. Let g I' be the line integral of magnetic force from a point on one pole piece to a point on the other, the line being drawn external to the armature, g will be approximately constant. Omitting as comparatively unimportant the magnetising force in the pole pieces and iron core of the armature we have the following equations:—

$$4\lambda m C + 2 l_2 \frac{I}{A_2} - g I' = 0$$

$$4\lambda m C + 2 l_2 \frac{I}{A_2} + l_3 f\left(\frac{I + I'}{A_3}\right) = 4\pi n c.$$

When $c = 0$ we observed

$$I = \frac{1}{\nu - 1} I'$$

whence

$$g = \frac{1}{\nu - 1} \frac{2 l_2}{A_2}$$

eliminating I'

$$\frac{2 l_2}{\nu A_2}\left(\nu I + 4\lambda m C \frac{A_2}{2 l_2}(\nu - 1)\right) + l_3 f\left\{\frac{\nu I + 4\lambda m C \cdot \frac{A_2}{2 l_2}(\nu - 1)}{A_3}\right\}$$

$$= 4\pi n c + 4\lambda m C \frac{\nu - 1}{\nu} - 4\lambda m C = 4\pi n c - 4\lambda m C \frac{1}{\nu}.$$

The characteristic curve when $c = 0$ being $I = F(4\pi n c)$ we may write the above as the equation of the characteristic surface thus

$$I + \frac{\nu - 1}{\nu} 4\lambda m C \frac{A_2}{2 l_2} = F\left(4\pi n c - \frac{4\lambda m C}{\nu}\right).$$

In applying this equation it must not be forgotten that the E.M.F. of the machine cannot be determined from I unless the commutation occurs at such a time that the coil being commutated embraces all, or nearly all, the lines of induction in the armature.

This equation enables the characteristic surface to be constructed from the characteristic curve. Let $OL = 4\pi n c$, $LM = 4 m \lambda C$, draw MK so that $\frac{KL}{LM} = \frac{1}{\nu}$, through K draw ordinate KR meeting characteristic curve in R, draw RQ parallel to OL meeting ordinate QL in Q, draw QS parallel to LM; draw QP so that $\frac{PS}{SQ} = \frac{\nu - 1}{\nu} \cdot \frac{A_2}{2 l_2}$. Then P is a point on the characteristic surface.

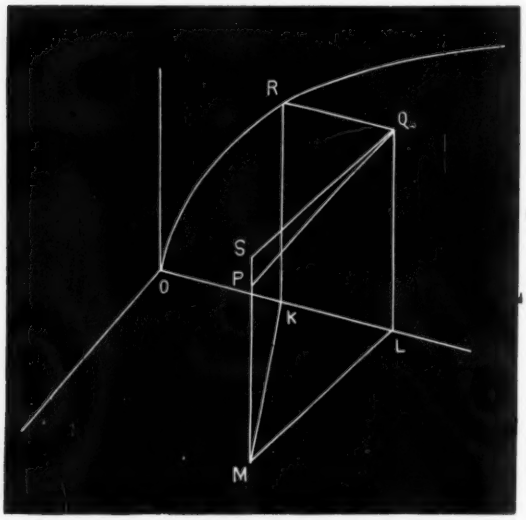


FIG. 5.

A very important problem is to deduce the characteristic curve of a series wound machine from the normal characteristic; in this case $c = C$, and we have

$$I + \frac{\nu - 1}{\nu} 4\lambda m C \frac{A_2}{2 l_2} = F\left\{\left(4\pi n - \frac{4\lambda m}{\nu}\right) C\right\}$$

taking PR as ordinate of any point in the normal characteristic, cut off QR equal to $\frac{\nu - 1}{\nu} 4\lambda m C \frac{A_2}{2 l_2}$, that is, draw OQ so that

$$\tan QOx = \frac{\nu - 1}{\nu} 4\lambda m C \frac{A_2}{2 l_2} / 4\pi\left(n - \frac{m\lambda}{\nu\pi}\right) C$$

$$= \frac{\nu - 1}{\nu} \frac{A_2}{2 l_2} \frac{\lambda m}{\pi n - \frac{\lambda m}{\nu}}$$

then PQ will represent the induction corresponding to magnetising force $4\pi\left(n - \frac{m\lambda}{\nu\pi}\right) C$.

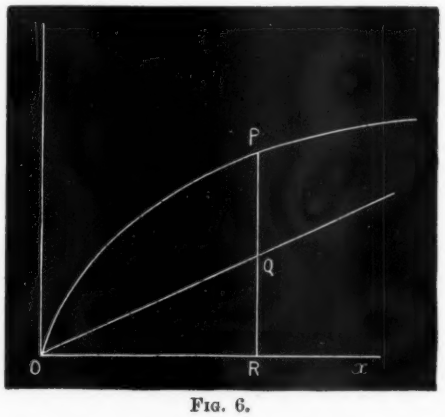


FIG. 6.

It is noteworthy that as the current C, and therefore OR increases, PQ, the induction, will attain a maximum and afterwards diminish, vanish, and become negative. That in series-wound machines the E.M.F. has a maximum value has been many times observed. The cause lies in the existence of a waste field not passing through the armature, and in the saturation of the magnet core.

The effect of the current in the armature on the potential between the brushes of any machine is the same as that of an addition to the resistance of the armature proportional to the lead of the brushes, and to the ratio of the waste field to the total field, combined with that of taking the main current $\frac{m\lambda}{\nu\pi}$ times round the magnets in direction opposite to the current c. The preceding investigation tells the whole story of a dynamo machine, excepting only the relation of λ to C in order that the brushes may be so placed as to avoid sparking. The only constant or function which has to be determined experimentally for any particular machine is ν, the ratio of total to effective field; all the rest follows from the configuration of the iron and the known properties of the material.

The following illustrations of the effect of the current in the armature and the lead of the brushes are interesting. In both cases the magnet coils are supposed to be entirely disconnected so that c is zero. First, let λ be negative, short circuit the brushes and drive the machine at a certain speed, a large current will be produced, the current in the armature itself forming the magnet.* Second, let λ be positive, cause a current to pass through the armature, the armature will turn in the positive direction and will act as a motor capable of doing work. In either case, particularly the former, such use of the machine would not be practical owing to violent sparking on the commutator. The following is a further illustration of the formula given above. If we could put up with the sparking which would ensue, it would be possible to make λ negative in a generator of electricity, and thereby obtain by the reactions of the armature itself all the results usually obtained by compound winding.

Efficiency Experiments.

Having discussed the relations subsisting between the configuration of the magnetic circuit of a dynamo machine and the induction obtained for given magnetising forces, and having compared the results obtained by direct calculation with the results of actual observation on a particular machine, the construction of which we have described at length, it appeared of importance to determine the efficiency of the machine under consideration as a converter of energy, when used either as a generator of electricity or as a motor. An accurate determination of the mechanical

[* Added August 17.—This experiment was tried upon a dynamo machine of construction generally similar to that shown in figs. 3, 4, 5, Plate 18, but with an armature of half the length intended in normal work to give 400 ampères 50 volts at 1,000 revolutions. The magnet coils were disconnected, and the terminals of the armature were connected through a Siemens electro-dynamometer, and the machine was run at 1,380 revolutions. When the brushes were placed in the normal position ($\lambda = 0$) the current due to residual magnetism was 52 ampères. By giving the brushes a small positive lead the current was reduced to nearly zero. By giving the brushes a small negative lead a current of over 234 ampères, the maximum measured by the dynamometer, was obtained, and by varying the lead it was easy to maintain a steady current of any desired amount.]

power transmitted to a dynamo by a driving belt, or of the power given by a motor presents formidable experimental difficulties. Moreover, if the mechanical power absorbed in driving the dynamo be measured directly, any error in measurement will involve an error of the same magnitude in the determination of the efficiency. To avoid this difficulty, we employed the following device.

Let two dynamos, approximately equal in dimensions and power, have their shafts coupled by a suitable coupling, which may serve also as a driving pulley; and let the electrical connections between the dynamos be made so that the one drives the other as a motor. If the combination be driven by a belt passing over the coupling pulley, the power transmitted by the belt is the waste in the two dynamos and the connections between them. By suitably varying the magnetic field of one of the dynamos, the power passing between the two machines can be adjusted as desired. If, then, the electrical power given out by the generator is measured, and also the power transmitted by the belt, the efficiency of the combination can be at once determined. By this arrangement the measurement, which presents experimental difficulties, viz., the power transmitted by the belt, is of a small quantity. Consequently, even a considerable error in the determination has but a small effect on the ultimate result. On the other hand, the measurement of the large quantity involved, viz., the electrical power passing between the two machines, can without difficulty be made with great accuracy.

The second machine was similar in all respects to that already described, and each is intended for a normal output of 110 volts, 320 ampères, at a speed of 780 revolutions per minute.

The power transmitted by the belt was measured by a dynamometer of the Hefner-Alteneck type, the general arrangement being as shown in the diagram, Plate 18.* A is the driving pulley of the engine, B the driven coupling of the dynamos; D, D are the guide pulleys of the dynamometer carried on a double frame turning about the fulcrum C, and supported by a spiral spring, the suspension of which can be varied by a pair of differential pulley blocks attached to a fixed support overhead. When a reading is made the suspension of the spring is adjusted until the index of the dynamometer comes to a fiducial mark on a fixed scale, the extension of the spring is then read by a second index attached to its upper extremity; F, F are two fixed guide pulleys of the same diameter as the pulleys D, D, and having the same distance between their centres, in order that the two portions of the belt may be parallel and the sag as far as possible taken up. The normal from C to the centre line of either portion of the belt between the pulley A and the guide pulleys = 31·9 cms. The normal from C to the centre line of either of the parallel portions of the belt = 2·4 cms.; and from C to the centre line of the spring = 92·7 cms.

Take moments about C; then

$$\text{Tension of the belt} = \frac{92{\cdot}7}{34{\cdot}3} \times \text{tension of spring},$$

$$= 2{\cdot}7 \times \text{tension of spring}.$$

Also the diameter of the pulley B = 33·6 cms. and the thickness of the belt = 1·6 cm.

Hence the velocity of the centre of the belt in centimetres per second = 1·845 × revolutions of dynamo per minute, and, therefore,

Power transmitted by the belt in ergs, per second

= 2·7 × 1·845 × 981 × tension of spring × revolutions per minute,

assuming the value of g to be 981.

We may more conveniently express the power in watts (= 10^7 ergs per second), and write—Power in watts = ·0004887 × tension of spring × revolutions per minute.

The potential between the terminals of the generator was measured by one of Sir William Thomson's graded galvanometers, previously standardised by a Clark's cell, which had been compared with other Clark's cells, of which the electromotive force was known by comparison with Lord Rayleigh's standard. The current between the two machines was measured by passing it through a known resistance, the difference of potential between the ends of the resistance being determined by direct comparison with the Clark's standard cell, according to Poggendorff's method. As experiments were made with currents of large magnitude, it was important that the temperature coefficient of the resistance should be as low as possible. To this end we found a resistance frame constructed of platinoid wire of great value. The temperature coefficient of this alloy is only 0·021 per cent. per degree centigrade. (Proc. Roy. Soc., vol. 38, p. 265 (1885.)

The resistances of the armatures and magnets of the two machines are as follows:—

		Ohms.
Generator	armature	0·009947
	magnets	16·93
Motor	armature	0·009947
	magnets	16·44

The resistance of the leads connecting the two machines was 0·00205 ohm, and of the standard resistance 0·00586 ohm.

In all determinations of resistance, the value of the B.A. ohm was taken as $0{\cdot}9867 \times 10^9$ C.G.S. units, according to Lord Rayleigh's determination.

(To be continued.)

* See ELECTRICAL REVIEW for March 5th, 1886.

THE BRITISH ASSOCIATION.

ON THE ACCURACY OF OHM'S LAW IN ELECTROLYTES.

By Prof. G. F. FITZGERALD, F.R.S, and Mr. TROUTON.

(Section A.—Mathematical and Physical Science.)

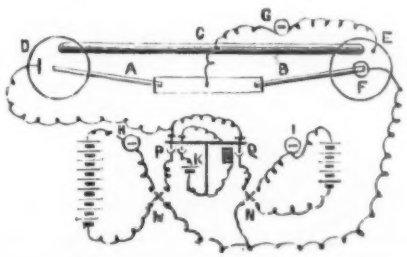
Tuesday, September 7th.

SOME preliminary experiments were begun in the spring of this year, and have been carried on from time to time since, with a view to determining how far Ohm's law may be relied on in the case of electrolytes.

Though as yet no very high limits of accuracy in the experiments have been attained, owing to causes which will be later on explained, still it is hoped that from the experience already gained most of the difficulties have been got over, and that soon results of a much greater degree of accuracy will be arrived at.

The method adopted is that described in the British Association Report for Glasgow, 1876, which Prof. Chrystal, in connection with Clerk Maxwell, employed in the case of metal conductors, namely, that of a Wheatstone bridge, two of the arms of which are of about equal section and resistance, while the remaining two, though of equal resistance, are of very different sections. If Ohm's law be not true, the point of balance of the bridge varies with the amount of current passing through it. Balance having been obtained, the battery-power is altered, and if balance still subsists, the deviation from Ohm's law, if there be any, is such as cannot be detected with apparatus of the sensitiveness employed.

The great difficulty in experimenting in this way is that the change in the current alters the temperature of the two arms of unequal section very differently, and proportionately also their resistances. While the thick conductor alters little in temperature, the thin one alters considerably. Thus the point of balance is changed, even though Ohm's law be true. To avoid this effect it is necessary, having balanced with the large current, to immediately pass the smaller current before the temperature can sensibly alter. As this requirement is practically impossible to satisfactorily fulfil, the method employed is a rapid alternation of a large and small current. If Ohm's law be not true, a balance in this case can only be apparent, and on reversing the direction of one of them, the two currents, which before neutralised each other's action, now conspire to deflect the galvanometer. The mode of experimenting is to find balance with a large and a small battery alternately in circuit, and rapidly enough for the



temperature during the smaller current to be sensibly the same as while the larger one is acting, then to change the direction of one of the currents and to again balance. The distance is observed between the two points of balancing, but if the bridge still balances it is assumed for the purposes of calculation that the distance is what the galvanometer employed only just detects. From this, from the two currents the section and resistance of the thin conductor, h is calculated where $c = rc\ (1 - hc^2)$, as is explained in the above-mentioned report.

The liquid chosen for experimenting with was a solution of copper sulphate in water. The equal arms consisted of two glass tubes bent at right angles at each end, A and B, arranged syphon-like, and contained the solution. They dipped into a long narrow trough, as shown in the diagram. The arm of large section, C, a tube 119 cm. long and 2·38 cm. in internal diameter, reached from the bowl, D, into which the tube, A, also dipped, to the bowl, E. The small arm was a hole ·055 cm. in diameter, drilled in the side of the beaker, F, ·062 cm. in thickness, into which the tube, B, dipped.

The battery poles consisted of copper plates, one in the beaker, the other in the bowl, D. The contact breaker was a T piece worked by an electromagnet and cell, K, as shown in the diagram. One of the batteries contained ten Grove cells, the other five, and both could be thrown in circuit in either direction by means of the reversing keys, M and N. By proper adjustment of the mercury cups, P and Q, one of the batteries went in circuit, just as the dipper on the other side, coming out of the mercury, threw the second battery out of circuit. By means of the galvanometers, H and I, it could be seen, during the course of an experiment, whether the contacts were working properly or not.

One of the copper wires leading to the galvanometer dipped into the bowl, E, the other into the trough, and could be moved up and down it in order to obtain balance, the distance moved being read off a scale along the trough. There was always more or less of a permanent current through the galvanometer, even

though the poles were both of copper; this, especially as it was liable to sudden changes in amount, caused by moving the trough pole or by accidental shaking, necessitated the employment of the galvanometer in a comparatively insensitive condition. Various devices were tried with a view of avoiding this current, such as electroplating the poles, using chemically pure copper sulphate, or employing for poles either end of a broken wire, so as to have, if possible, metallically like poles. These were found to give an indication of current even in distilled water.

The resistance of the smaller arm was about 800 ohms, but owing to its smallness varied greatly with the current through the change of temperature. A good deal of trouble was experienced through the resistance of the smaller arm at times being less when the current passed in one direction than when it passed in the other. This occurred so often that until its cause was understood, and steps thus could be taken to prevent it, there was little hope of completing the experiments. After various attempts it was discovered to be due to the density of the solution on the outside of the beaker in the bowl being slightly different from that inside, so that the density in the hole, and consequently its resistance, depended on the direction of the current, the electric transfusion of the liquid always changing direction with the current.

A number of experiments were made of a more or less satisfactory nature; in all no difference in the position of balance was found on reversing one of the batteries. Taking the difference, then, to be what the galvanometer would just detect, h is calculated to be less than 10^{-4}. This is, of course, very large. The limit Prof. Chrystal reached in his experiments with metal conductors was less than 10^{-12}.

With a view to reaching a higher limit a smaller hole was next tried. It was ·17 cm. in diameter drilled in a plate of glass ·022 cm. thick. Its resistance was about 2,700 ohms, so that a longer tube had to be used for the large arm. The balance was always found to be very different when one of the batteries was changed in direction. However, this was probably entirely due to the difference in temperature during the small and large currents, for h calculated from this was not even as small as in the first experiments; also the difference between the balance points varied with the speed of the contact breaker. Unfortunately the contact breaker, which was adjustable in its rate of vibration, had reached its limit of speed, so that a completely new arrangement has now to be employed.

ON DIATHERMANCY AND ELECTROLYTIC CONDUCTIVITY.

By SHELFORD BIDWELL, Esq., F.R.S.

THE following is one of the questions suggested by Dr. Lodge for the consideration of the committee on electrolysis:—Is there any relation between optical opacity and electrolytic conductivity?

Assuming that "optical opacity" is included in the more comprehensive term "opacity to radiation," I have endeavoured to ascertain experimentally whether those electrolytes which transmit radiation with the greatest facility, as evidenced by the effect produced upon a thermopile, are also the worst conductors of electricity. I may say at once that this was undoubtedly not the fact, and the relation which was supposed to be possible does not exist.

Considerable time and care were bestowed upon the experiments, and every precaution was taken with the view of ensuring accuracy. The thermopile used was a delicate one, containing 54 bismuth-antimony pairs; it was enclosed in a flannel-covered box, fitted with a pane of glass 1·5 mm. thick opposite the face of the pile. The galvanometer was an astatic reflecting instrument of ·545 ohm resistance made by Elliott. The source of radiation was a small paraffin lamp, having a glass chimney about 2 mm. thick.

The parallel glass sides of the cells, used to contain the liquids, were 13 mm. apart and 1·9 mm. in thickness. A screen, with a small aperture, which could be instantly opened or closed by a sliding shutter, was interposed between the cell in use and the lamp. The various solutions were in every case exposed to radiation for a period of 30 seconds, and each observation was checked and standardised by the aid of a certain cell containing water. It is hardly necessary to describe the arrangements and method of observation in greater detail.

A few of the results, which, for the most part, need no comment, are given in the following table:—

Solutions, &c.	Diathermancy.	Solutions, &c.	Diathermancy.
Empty cell	1,000	Zinc sulphate sol. sp. gr. 1·157	207
Water distilled	197	Sulph. acid 1·032 (5 per cent.)	208
,, from tap	200	,, ,, 1·225 (30 ,,)	216
Alum saturated solution ..	204	,, ,, 1·638 (72 ,,)	282
Ammonium chloride solution	215		

The observations with sulphuric acid are the most instructive. It is well known that the electrical conductivity of sulphuric acid at first increases with the concentration, reaching a maximum when the strength of the solution is about 30 per cent., and afterwards rapidly diminishing. That there is no corresponding minimum diathermancy appears clearly enough from the above table, which seems to furnish a conclusive answer in the negative to the question proposed.

The diathermancy of a solution of zinc sulphate was almost independent of its strength, being nearly the same for a 5 per cent. as for a saturated solution. It was quite unaffected by the passage through the solution of a strong battery current.

THE CHELSEA ELECTRIC LIGHTING ACT.

UPON the records of private legislation during the past year there appears one solitary measure for the promotion of electric lighting. This is the Chelsea Electric Lighting Provisional Order, confirmed under the Act of 1882, and passed as an Act of Parliament by itself. In this measure there are no less than 85 separate clauses, and three schedules, and very minute and complete these provisions are. In some quarters these exhaustive conditions may be regarded as calculated to strangle rather than encourage electric light, but with that point we are not now concerned, our object being to show what the Act does. After the enacting and defining clauses, it is provided that the undertakers may, subject to the approval of the Board of Trade, supply a certain area (set forth in the schedules), and on the same conditions extend or reduce the area, after due public notice. The initial capital is to be not less than £100,000, £2,000 of which must, within a year after the commencement of the Act, be deposited, in respect to the area in schedule A; and three-fourths of the amount required for that area must be *bonâ fide* subscribed within two years. The capital must be set aside as separate capital for the undertaking, and must be increased when the area of supply is increased on the same terms as at the beginning. Clause 12 deals with the nature and mode of the supply, and declares that "The undertakers may supply electricity within the area of supply for all public and private purposes as defined by the Act, provided that such electricity shall be supplied only by means of some system which may have been approved of by the Board of Trade either for general or special use, and subject to such regulations and conditions for securing the safety of the public, and for ensuring such a proper and sufficient supply of electricity as the Board of Trade may from time to time impose, and that under no such system shall the undertakers permit any part of any circuit to be connected with earth, except so far as may be necessary for carrying out the provisions of any such regulations or conditions as aforesaid, unless such connection is hereafter approved of by the Board of Trade, with the concurrence of the Postmaster-General."

Powers for breaking up streets, or other public ground, and constructing distributing boxes, are next given; and clause 14 requires notice of works, with plans and full particulars to be submitted to the Postmaster-General and the local authorities. Upon this point the following sub-section is very important in view of recent discussion and controversy:—"Where the Postmaster-General or the local authority disapprove of any such works or plan, the undertakers may appeal to the Board of Trade against such disapproval, and the Board of Trade may inquire into the matter and allow or disallow such appeal, and approve any such works or plan, with or without any amendments or alterations, or disapprove the same: provided that nothing in this Order shall authorise the undertakers to place any electric line above ground, along, over, or across any street without the express consent of the local authority." In the next place the rights of railway, tramway, canal, or other private property are carefully safeguarded; and section 16 gives power to local authorities, railway ond other owners, to break up streets on behalf of the electric undertakers. Numerous conditions are laid down respecting the alteration of pipes or wires under streets, and laying down electric lines near gas, or water, or drain pipes; and with respect to the protection of telephone wires it is provided (by clause 19) that:—"Seven days before commencing to lay down any electric line, or to supply electricity through any electric line in any manner whereby the work of telegraphic or telephonic communication through any wires or lines lawfully laid down or placed in any position may be injuriously affected, the undertakers shall, unless otherwise agreed between the parties interested, give to the body or person for the time being entitled to such wires or lines notice in writing specifying the course, nature, and gauge of such electric lines, and the amount and nature of the current intended to be sent along the same, and the extent to and manner in which, if at all, earth returns are proposed to be used; and the undertakers shall conform with such reasonable requirements as may from time to time be made by such body or person as aforesaid for the purpose of preventing the communication through such wires or lines from being injuriously affected as aforesaid."

Any dispute is to be decided by arbitration, and penalties and compensation in case of non-compliance with the section are defined. Several clauses following are devoted to compulsory works and supply upon requisition by local authority or private persons, limitations being fixed as to period of such supply and payment. Other clauses provide for the appointment of electric inspectors by local authorities or courts of summary jurisdiction, the remuneration of such inspectors, the testing of mains and service lines and the establishment of testing stations by local authorities. With regard to supply the 44th clause declares that "The undertakers shall, upon being required so to do by the owner or occupier of any premises situate within twenty-five yards from any distributing main of the undertakers in which they are, for the time being, required to maintain a current of electricity for the purposes of general supply to private consumers under this order or any regulations and conditions, subject to which they are authorised to supply electricity under this order, give and continue to give a supply of electricity for such premises in accordance with the provisions of this Order, and of all such regulations and conditions as aforesaid, and they shall furnish and lay any electric lines that may be necessary for the purpose of supplying the maximum current with which any such owner or occupier may be entitled to be supplied under this Order"—subject to the owner or occupier taking the supply defraying the

cost of so much of the electric line as is on his property, and so much as is more than 30 feet from any distributing main; and to certain specified notices. The undertakers are protected against the use of the light by any consumer in such a way as to interfere with the supply to any other persons. Public supply is dealt with by Section 46, which requires undertakers to supply electricity upon proper and reasonable notice to any public lamps within 50 yards of a distributing main, and in such quantities as the public authority may require. The penalty for not supplying a private owner or occupier is forty shillings for each day of non-supply; and for not supplying the public lamps forty shillings each lamp each day. These penalties are however thus qualified:—"Provided that the penalties to be inflicted on the undertakers under this section shall in no case exceed in the aggregate the sum of fifty pounds in respect of any defaults not being wilful defaults on the part of the undertakers for any one day, and provided also that in no case shall any penalty be inflicted in respect of any default if the court having cognizance of the case are of opinion that such default was caused by inevitable accident or force majeure or was of so slight or unimportant a character as not materially to affect the value of the supply, or where such court are of opinion that such default was not wilful on the part of the undertakers, or due to any negligence on the part of the undertakers or any of their officers or servants, and that all reasonable precautions have been taken by the undertakers to prevent the occurrence of such default."

Coming next to the question of price, the Act enacts (Clause 48) that the undertakers may charge for electricity supplied by them from any distributing main to any ordinary consumer (otherwise than by agreement):—(1.) By the quantity of energy contained in such supply; or, (2.) By the actual quantity of electricity so supplied; or, unless the Board of Trade from time to time otherwise direct, (3.) By the number of hours during which the supply of electricity is actually used by such consumer, and the maximum current with which he is for the time being entitled to be supplied—provided however that before commencing to supply electricity through any distributing main for the purposes of general supply, the undertakers shall give notice to the local authority by what method they propose to charge for electricity supplied through such main; and, where the undertakers have given any such notice, they shall not be entitled to change such method of charging except after one month's notice of such change has been given by them to the local authority and to every consumer of electricity who is supplied by them from such main.

The maximum prices that may be charged are set forth in Schedule C:—("The term 'unit' as used in this schedule shall be deemed to mean the energy contained in a current of 1,000 ampères flowing under an electromotive force of one volt during one hour.") "Section 1.—Where the undertakers charge any consumer by the quantity of energy contained in the supply given to him, they shall be entitled to charge him at the following rates per quarter:—For any quantity up to 84 units, £3 10s.; and for each unit over 84 units, 10d. per unit. Section 2.—Where the undertakers charge any consumer by the actual quantity of electricity supplied to him, they shall be entitled to charge him according to the rates set forth in Section 1 of this schedule, the quantity of energy contained in the supply given to him being taken to be the product of the actual quantity of electricity supplied to him, and the standard pressure at the point of junction of the mains and the service lines by which he is supplied. Section 3.—Where the undertakers charge any consumer by the number of hours during which he actually uses his supply, they shall be entitled to charge him at the rates specified in Section 2 of this schedule, the quantity of electricity supplied to him being calculated on the supposition that the consumer uses the maximum current specified by him under the provisions of this Order during all the hours that he has used the supply."

Subject to these limitations, however, the undertakers may make any agreement with a consumer as to the price, and the mode in which the charges are ascertained; and as to the public supply, the charges are to be settled by agreement, or, in case of difference, by arbitration; "regard being had to the circumstances of the case and the distributing of other mains which may have been laid for the purpose and the prices charged to ordinary consumers in the district." The remaining clauses of the Act deal with the supply and maintenance of meters, the revocation of the Order—through insolvency of the undertakers, or unprofitable results, or with the consent of the undertakers and local authorities; with the recovery of penalties, liability for damage; with the rights and privileges of the Crown, the Postmaster-General, the Thames Conservancy, and the West London Extension Railway; and with sundry other matters of the usual kind.

THE SUBMARINE TELEGRAPH ACT.

DURING the last Session of Parliament an Act bearing upon telegraph cables was introduced and passed without attracting any general attention. By Article 4 of the schedule to the Submarine Telegraph Act of 1885 it was provided, that "The owner of a cable who, on laying or repairing his own cable breaks or injures another cable, must bear the cost of repairing the breakage or injury, without prejudice to the application, if need be, of Article 2 of the present convention." (Article 2 laid down, that 'It is a punishable offence to break or injure a submarine cable wilfully, or by culpable negligence, in such manner as might interrupt or obstruct telegraphic communication, either wholly or partially, such punishment being without prejudice to any civil action for damages;" and that "This provision does not apply to cases where those who break or injure a cable do so with the lawful object of saving their lives or their ship, after they have taken every necessary precaution to avoid so breaking or injuring the cable.") Article 2 was, however, qualified by clause 2 of the Act, which declared that that article "shall not apply to that part of a cable which is laid in a depth of water exceeding 100 fathoms; but nothing in this convention shall take away, prejudice, or affect any right or remedy to which by law any party is or may be entitled otherwise than under the provisions of the convention or this Act." In the application of this Act a stumbling block very speedily appeared, and last Session an amending Act was passed, which itself explains the difficulty. Section 4 of the Act of 1885 was repealed, and by the third clause it was enacted that the schedule to the new Act should be of the same force as the articles of the convention set forth in the schedule to the Act of 1885; and the schedule ran thus:

"Certain doubts having been raised as to the meaning of the word 'wilfully' used in Article 2 of the convention of the 14th of March, 1884, it is understood that the provision in respect of penal responsibility contained in the said article does not apply to cases of breakage or injury caused accidentally or of necessity in the repair of a cable when all precautions have been taken to avoid such breakage or injury. It is equally understood that article four of the convention had no other object, and is to have no other effect, than to empower the competent tribunals of each country to decide in conformity with their laws and according to the circumstances the question of the civil responsibility of the owner of a cable who in laying or repairing his own cable breaks or injures another cable, as well as the consequences of such responsibility if it is recognised as existing."

The Convention to which these Acts apply was adopted in 1884 for the preservation of telegraphic communications by means of submarine telegraphs between Great Britain and Ireland, Germany, the Argentine Confederation, Austria, Belgium, Brazil, Costa Rica, Denmark, the Dominican Republic, Spain, the United States, Colombia, France, Guatemala, Greece, Italy, Turkey, Holland, Persia, Portugal, Roumania, Salvador, Servia, Sweden and Norway, and the Republic of Uruguay.

THE HEATING OF AERIAL CONDUCTORS BY ELECTRIC CURRENTS.*

By J. GILBERT WHITE, PH.D.

(*Concluded from page* 382.)

IN these experiments the wires were heated to barely the point of self-luminosity in a dark chamber. At this high temperature (about 526° C.) radiation becomes an important factor in the loss of heat, and we should, therefore, not expect the absolute emissive power to vary so much as at the low temperatures at which the experiments of Prof. Forbes, Mr. Bottomley, and those given in the first part of this paper were made. In the following tables, the current required to raise the largest wire to the required temperature, was taken as the basis of calculation. If the absolute emissive powers of the wires remained constant, we would have $C : C' :: d^{\frac{3}{2}} : d'^{\frac{3}{2}}$ and $C' = C\left(\frac{d'}{d}\right)^{\frac{3}{2}}$. An inspection of the tables shows that in every case, except two, the observed current was more than the calculated, the divergence becoming larger as the diameters decreased. This is fully explained on the theory that the absolute emissive power of the smaller wires, was the larger, and hence, a greater current than calculated was required to bring them to the desired temperature.

COPPER WIRE.

Diameter of wire in mils.	Observed current in ampères.	A.
30	23,969	23,969
24	16,832	17,151
20	13,711	13,047
18	11,269	11,140
14	7,654	7,641
8	3,849	3,300

PLATINUM WIRE.

Diameter of wire in mils.	Observed current in ampères.	D.
38	13,461	13,461
20	6,841	5,140
18	5,785	4,389
14	4,739	3,010
11	3,337	2,097
8	2,536	1,300

* New York *Electrician and Electrical Engineer.*

SWEDISH WROUGHT IRON.

Diameter of wire in mils.	Observed current in ampères.	B.
60	18,579	18,579
40	10,785	10,113
20	4,283	3,575
10	1,718	1,437

GERMAN-SILVER WIRE.

Diameter of wire in mils.	Observed current in ampères.	C.
25	7,047	7,047
20	5,106	5,042
16	3,916	3,608
14	3,743	2,953
8	1,257	1,276

The experiments of Prof. Forbes and Mr. Preece, made under such different circumstances, afford no means for determining even approximately what is the variation of the absolute emissive power for different diameters.

Hence the experiments described, and the data of which are given, were undertaken.

By laying off the temperatures as ordinates and the diameters in mils. as abscissæ, a curve of temperature is obtained. Equation (21) transposed gives

$$T = \frac{C^2 a}{2 \pi r^3 J E - C^2 a \phi}$$

If T and r vary, the other factors remaining constant, we would have T varying nearly as $\frac{1}{r^3}$; since $C^2 a \phi$ is small compared to $2 \pi r^3 J E$ for the C used in this case. If, however, E varies inversely with r, then T will vary less rapidly than $\frac{1}{r^3}$; that is, T will vary as one divided by a function of r, which function will be less than the cube. To get data for a curve showing this variation, calculations were made from table XXIV. By assuming that the temperature in a wire varies as the square of the current, which introduces no considerable error in this case, the temperature of the No. 20 wire and the one joined with it were reduced in every case to what they would be for a current of 7·16 ampères.

If the atmospheric conditions (draughts, &c.) had been constant, this should have been given in each case, for the No. 20 wire an increase in temperature of 18·14°, the T actually observed for the No. 20 wire with a current of 7·16 ampères for which current all the values of T were calculated. But the actual observed T for the No. 20 wire varied somewhat from the T calculated as above; and to get them the same it was necessary to apply a correction to the observed T to counteract changing external conditions. It was assumed that the T for the wire coupled with the No. 20 wire would have to be corrected by the same percentage of its value as the No. 20, which could introduce no appreciable error, as the correction itself was in every case small.

The following table was made out as just indicated:

Current in ampères.	T of movable wire observed.	T of No. 20 wire observed.	T of No. 20 wire calculated for C = 7·16.	T of movable wire calculated for C = 7·16.	Corrected T of movable wire for C = 7·16.	Diameter of wire in mils.
17·03	10·33	116·1	20·59	1·83	1·63	78·9
13·61	21·4	65·9	18·30	5·94	5·89	49·1
14·18	40·93	80·23	20·41	10·41	9·29	39·8
7·16	...	...	...	...	18·14	30·8
7·16	61·34	18·14	18·14	61·34	61·34	19·4
3·84	47·89	5·29	18·35	166·18	164·29	11·96

Curve 1, plate III., was plotted from the table just above.

Curve 2 on the same plate was drawn by assuming that T varied as $\frac{1}{r^3}$. The divergence between the two lines is due, of course, to the increase in the absolute emissive power for the small wires.

But this shows, only after calculation, the variation of the emissive power. If, however, we use equation (21)

$$E = \frac{C^2 a (1 + \phi T)}{2 \pi^2 r^3 J T}$$

we can calculate the values of E from the experimental data. By the method employed of using one wire as a basis of comparison we have

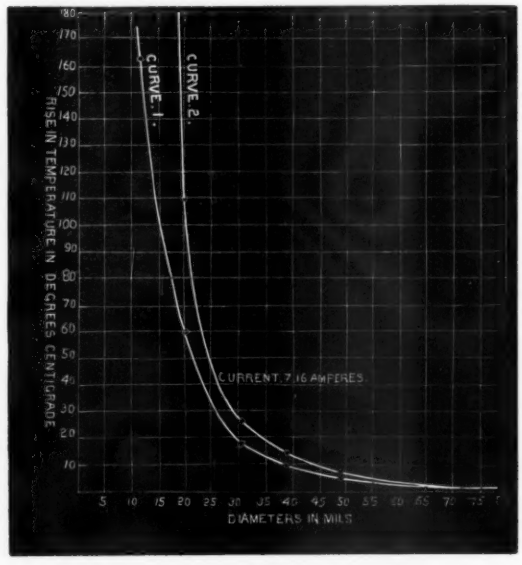


PLATE III.

$$\frac{C^2 a}{2 \pi^2 J}$$

common to the equations for both wires; hence we will have

$$E : E' \; : : \frac{1 + \phi T}{r^3 T} : \frac{1 + \phi T'}{r'^3 T'}$$

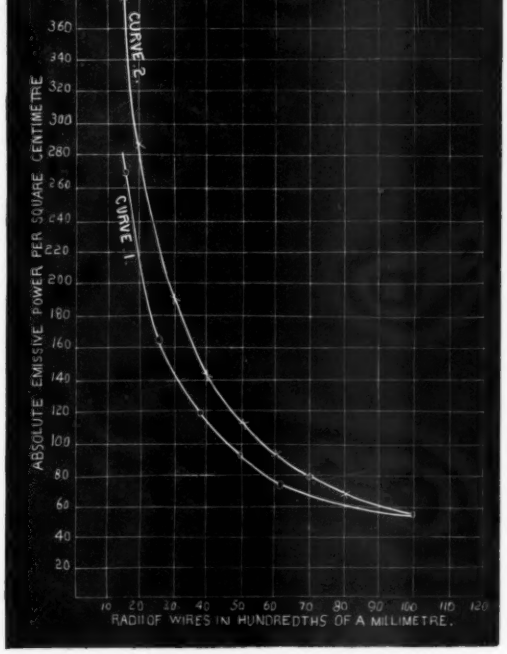


PLATE IV.

Having calculated E by equation (21) for the wire used as a standard, all the other values of E can be calculated from the proportion just given, then laying off the values of E as ordinates, and the corresponding

diameters as abscissæ, a curve is obtained representing directly the variation of E. If E were constant the line would be straight and run parallel to X.

From table XXIV. we get the data for the following table, the values of E, being obtained by calculating E for the No. 20 wire by equation (21), assuming a value for a of 1.652×10^{-6}, as given in Prof. Everett's "Units and Physical Constants." The other values of E were calculated from the proportion given on the preceding page.

No. of wire.	Radius of wire in centimetres.	Current in ampères.	ϕ T	T	ϕ T′	T′	E. Absolute emissive power.
12	0·1002	17·03	45·03	116·1	4·01	10·33	0·000569
16	0·0625	13·61	25·57	65·9	8·31	21·40	0·000773
18	0·0505	14·18	31·13	80·23	15·88	40·93	0·000956
20	0·039	13·61	25·57	65·9	...	...	0·001198
24	0·0245	7·16	7·04	18·14	23·80	61·34	0·001653
28	0·015	3·84	2·05	5·29	18·58	47·89	0·002703

We have already quoted, as seeming very reasonable, the view of Prof. Forbes; that for small wires the loss of heat due to radiation is proportional to the diameter, but the loss due to convection is nearly constant. As the loss due to radiation is small compared to the loss due to convection, the total emissive power of unit length of the wire would be nearly constant.

But the total emissive power of unit length equals the absolute emissive power multiplied by a constant times the diameter.

If the total emissive power were constant, we would have $E\,r = \text{constant}$ ∴ or $E = \frac{1}{r} \times \text{constant}$, the equation of an hyperbola. Curve 2, plate IV., was drawn by assuming the preceding equation to be true, and starting with the value of E given by curve 1 when r was 100. Curve I was plotted from the values of E, obtained by calculation as previously explained and given in the preceding table. The divergence between the two curves is just such as Prof. Forbes's view would lead us to expect.

Another problem of at least theoretical interest is, what is the relation of the excess of temperature at the centre of a bare wire over that at the surface, both being maintained at a temperature above that of the surrounding air by a uniform current.

A very good solution has been given by Mr. Perenyi, and we will again translate from *La Lumière Electrique* (Tome xiv., page 255). "It is in effect logical to admit the law already established, that there is a transmission of heat from one layer to the neighbouring concentric layer, and that the temperature is more and more elevated as we approach the centre.

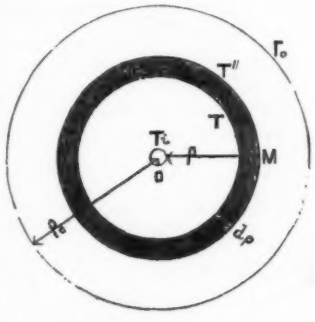


FIG. 2.

In order to simplify as much as possible the calculation, let us suppose that the coefficient of specific resistance remains constant between T_0 and T_i, T_0 representing the excess of the temperature of the surface above the surrounding medium, and T_i that of the central point. This hypothesis contains nothing exaggerated, since the coefficient in question is modified but little by the temperature; though we may reach a still greater approximation by taking for a (specific resistance) a mean value corresponding to the mean of T_0 and T_i.

This being understood, we may admit that the quantity of heat, d H, generated per second in a layer of infinitely small thickness, $d\,p$, fig. 2, is to the quantity of heat generated in the whole section in the same time, as the annular section is to the whole section, the conductor being considered of unit length. We then have

$$d\,H = H_0 \frac{2\,\pi\,p\,dp}{\pi\,p_0^2} = \frac{H_0^2\,p\,dp}{p_0^2} \qquad (h)$$

But the quantity of heat which traverses the circle M is equal to the sum from o to H of the elementary quantities, d H; hence

$$H = H_0 \int_{-o}^{-p} \frac{2\,p\,dp}{p_0^2} = H_0 \frac{p^2}{p_0^2} \qquad (i)$$

On the other hand, if we call T″ the excess of temperature corresponding to the circle of radius, p and T′, that which corresponds to radius $p + dp$, the increase of temperature for an increase radius, dp will be $-d$T, since the temperatures diminish as the radii increase.

The quantity of heat which traverses the ring, M, per second is directly proportional to the surface, to the coefficient of conductivity, K, and to the difference of temperature $-d$T, and inversely proportional to the thickness, dp. This quantity is, therefore, expressed by

$$H' = -\frac{K\,2\,\pi\,p\,dT}{dp} \qquad (j)$$

Having supposed the law established, it is evident that we should have H = H′, which gives by equalising (i) and

(j), $$-dT = \frac{H_0\,p\,dp}{2\,\pi\,K\,p_0^2}$$

Finally, integrating one part between the limits T_i and T_0 and the other between o and p we get

$$T_i = \frac{H_0}{4\,\pi\,K} + T_0,$$

an equation which may be written

$$T_i = M\left(\frac{C}{d}\right)^2 + T_0, \quad M \text{ being a constant.}$$

Or put in words, this formula means that the difference of temperature between the central point and the surface is (very nearly at least) directly proportional to the square of the current and inversely proportional to the square of the diameter.

A still more interesting, and, as we shall see, more practical problem is, what is the effect on the temperature of a wire putting around it an insulating covering? Let T be the excess of temperature over surrounding air of a bare wire in the permanent state:

T′ that of the same surface after the insulating covering has been put on;

T_i that of outside of insulation;

E = absolute emissive power of bare wire;

E_i = „ „ „ „ insulation;

r_0 = radius of bare wire;

r_i = „ „ insulation;

K = conductivity of insulating material.

Considering first a very thin layer of insulation of thickness, $d\,r$, and radius, r, the surface of this layer for unit length is $2\,\pi\,r$; hence we may derive directly from the definition of conductivity, the heat conveyed through this layer.

$$= H = \frac{K\,2\,\pi\,r\,dT}{dr} \qquad (21)$$

d T being the difference of temperature of outside and inside of layer dr, transposing

$$\frac{dr}{r} = \frac{K\,2\,\pi}{H}\,dT \qquad (22)$$

$$\int_{r_B}^{r_i} \frac{dr}{r} = \int_{T_i}^{T'} \frac{2\pi K}{H} dT$$

$$\log_e r_i - \log_e r_B = \frac{2\pi K}{H}(T' - T_i)$$

$$\therefore T' - T_i = \frac{H}{2\pi K}\log_e \frac{r_i}{r_B}. \quad T_i = T' \frac{-H}{2\pi K}\log_e \frac{r_i}{r_B} \qquad (23)$$

But the heat which passes through the covering must equal that given off from the bare wire in the first case and from the insulation in the second, since we supposed the temperature to be in the permanent state in each case; and no change made in current or resistance. Therefore

$$H = 2\pi r_B E T = 2\pi r_i E_i T_i \qquad (24)$$

Substituting in (23):

$$T_i = T' - \frac{2\pi r_i E_i T_i}{2\pi K}\log_e \frac{r_i}{r_B} \qquad (25)$$

This shows us that whatever the current the ratio of T_i to T' should be constant, since we may write

$$\frac{T_i}{T'} = \frac{1}{1 + \frac{r_i E_i}{K}\log_e \frac{r_i}{r_B}}$$

$$\therefore \frac{T}{T'} = \frac{r_i E_i}{r_B E\left(1 + \frac{r_i E_i}{K}\log_e \frac{r_i}{r_B}\right)} \qquad (26)$$

Of course this equation is not exactly correct since the resistance will change with the change of temperature; but, since the resistance changes in proportion to the temperature, the corrections to be added to T_i T' will have nearly the same ratios as themselves, and the ratio will not be appreciably changed. The agreement of this result with the result of the foregoing experiments is given below.

T' and T were read from the cross-section paper for currents taken at random.

T	T′	$\frac{T}{T'}$	T	T′	$\frac{T}{T'}$
15·2	7·9	1·92	35·7	19·2	1·86
18·8	9·8	1·92	40·2	21·6	1·87
21·8	11·3	1·90	50·0	26·3	1·90
28·0	14·9	1·88	61·5	31·8	1·93
32·1	16·8	1·91	82·7	42·8	1·93

Average of ten values ... ... 1·902

Equation (26) might be used to calculate T' from T, or *vice versâ*; but the constants K, E, and E_i are so little known that we must wait further experiments before the equation will be of much use in this way; but still it shows some useful facts. If in this equation

$$K = o,\ T' = \infty, \text{ but if } K = \infty : T' = \frac{E r_B T}{E_i r};$$

or T' can never be less than

$$\frac{E r_B T}{E_i r_i}$$

Moreover, an increase in K causes a decrease in T', hence in the permanent state, as well as before that state is reached, an insulation of high thermal conductivity is advantageous.

The specific heat of the insulation does not enter at all into this equation, and is, therefore, of consequence only for cases when the current does not flow for sufficiently long time to bring the conductor to its permanent state.

Equation (26) can also be used when some experiments have been made on wires of a particular kind, and we desire to find the ratio for other wires of the same kind; but to use the equation even in this way it will be necessary to first establish more fully than has been done the law of the variation of the absolute emissive power of a conductor with a variation of its diameter.

An inspection of equation (26) shows that when $r_i E_i$ = or > $r_B E$, T (the temperature of the bare wire) will always be greater than T' (the temperature of the insulated wire); for $\frac{r_i E_i}{K}\log_e \frac{r_i}{r_B}$ will always have a positive value.

We should, therefore, expect to find the temperature of the insulated wire less than that of the bare wire. That such is the case is shown by all the experiments recorded in this paper.

To show more clearly this relation the following table has been made out from Table xxv.

Kind of wire.	No. of wire.	$\frac{r_i}{r_B}$ = ratio of diam. of insulation to diam. of bare wire.	$\frac{T}{T'}$ = ratio of temp. of bare wire to temp. of insulated wire.	$\frac{\frac{r_i}{r_B}}{\frac{T}{T'}} = \frac{r_i\ T'}{r_B\ T}$
Underwriters	16	2·33	1·57	1·48
,, ...	18	2·71	1·65	1·64
Silk wrapped	16	1·04	1·26	0·826
Clark Co.'s ...	18	5·42	2·35	2·31
,, ...	18	6·06	2·62	2·32
,, ...	16	4·74	2·80	1·70
,, ...	14	4·75	2·55	1·86
Office ...	12	1·74	1·52	1·14
,, ...	16	2·16	1·55	1·40
,, ...	18	2·46	1·84	1·34
,, ...	20	2·92	1·81	1·61

This table and Table xxv. give some interesting results, and results which it is hoped may be of some use to those interested in the subject. Still these experiments were not sufficiently extensive and complete to enable us to calculate the constants involved in equation (26) nor to put on cross-section paper curves showing the variation of the permanent temperature with a variation of the thickness of its insulation, for the insulations used. It was hoped that a simple empirical formula might be derived which would readily admit of calculating the effect of any thickness of insulating coverings of the most common kinds.

But the law governing this variation is apparently so complex that a much more extensive set of experiments than those recorded in this paper will need to be made before such a formula, that will be assuredly accurate, can be derived. It is hoped that an opportunity for continuing and extending these experiments may ere long be found.

We are now in a position to discuss a problem which was logically the second part of problem I; that is the relation of the temperature of an insulated conductor and the time since the starting of an uniform current.

The heat developed is used to heat the wire, to heat the insulation, and to supply the loss of that given up to the surrounding medium.

The heat developed is, of course, as before, $\frac{C^2 R}{J}(1 + \phi T)\,dt$; for a small time dt. The heat used in the wire equals weight × specific heat × rise in temperature $= \frac{\pi r^2}{g} h\, dT$.

Similarly, the heat used in the insulation is

$$\frac{\pi (r_i^2 - r_B^2)}{g_i} h\, k\, dt,$$

k being a constant which expresses the ratio of the increase of the rise in the temperature of the wire to the rise of temperature of the insulation.

That k is a constant has been shown by the proof that the ratio of T and T_i is constant.

Finally, the heat lost equals $2\pi r_i E_i T_i$. These values put in the form of an equation give

$$\frac{C^2 R}{J}(1 + \phi T')\,dt = \frac{\pi r_B^2 h}{g} dT' + \frac{\pi (r_i^2 - r_B^2) \times h \times k \times dT'}{g_i} + 2\pi r_i E_i T_i. \qquad (27)$$

But from equation (26) we get

$$T_1 = \frac{T'}{1 + \frac{r_1 E_1}{K} \log_e \frac{r_1}{r_2}}$$ which substituted in (27) gives

$$\overbrace{\frac{C^2 R}{J}}^{H} (1 + \phi T)\, d t = \overbrace{\frac{\pi r_2^2 h}{g}}^{M} d T + \overbrace{\frac{\pi (r_1^2 - r_2^2) h k}{g}}^{S} d T + \overbrace{\frac{2 \pi r_1 E_1}{1 + \frac{r_1 E_1}{K} \log_e \frac{r_1}{r_2}}}^{N} T\, dt$$

Representing the cumbersome coefficients by single letters we have $H (1 + \phi T)\, dt = m\, (dT) + s\, (dT) + m T\, dt.$ (28)

$$dt = \frac{(m + s)\, dT}{H (1 + \phi T) - n T} = \frac{(m + s)}{H - (n - H \phi) T} dt$$

$$= \frac{v\, dT}{H - u T} \quad (29)$$

putting $v = m + s$ and $u = (n - H \phi)$

$$\int_0^t dt = \int_0^T \frac{v\, dT}{H - u t} \cdot t = -\frac{v}{u} \left(\log_e (H - u T) - \log_e H \right) \quad (30)$$

$$t = -\frac{v}{u} \log_e \frac{(H - u T)}{H} \quad (31)$$

$$\log_e \left(1 - \frac{u T}{H}\right) = \frac{-t u}{v} \quad (32)$$

$$1 - \frac{u T}{H} = e^{\frac{-t u}{v}} \quad (33)$$

$$T = \frac{H \left(1 - e^{\frac{-t u}{v}}\right)}{u} \quad (34)$$

Equation (34) is similar in form to that derived for bare wire, and written out in full is

$$T = \frac{H}{\frac{2 \pi r_1 E_1}{1 + \frac{r_1 E_1}{K} \log_e \frac{r_1}{r_B} - \phi H}} \left[1 - e^{-\left[\frac{t \left(\frac{2 \pi r_1 E_1}{1 + \frac{r_1 E_1}{K} \log_e \frac{r_1}{r_B}}\right) - \phi H}{\frac{\pi r_B^2 h}{g} + \frac{\pi (r_1^2 - r^2) h k}{g_1}}\right]}\right] \quad (35)$$

an equation too complex for use even if we knew the values of the constants.

Probably the most useful of all the problems connected with this subject is that of the economical size of wire for a given current. Sir Wm. Thomson was the first to prove a theorem, since much quoted, that the most economical conductor is that in which the cost per annum of the energy wasted in heating the wire is just equal to the annual cost of interest on and depreciation in the value of the conductor.

Then letting P = cost of an electrical horse-power per annum for the number of hours during which the plant is in use ; M = the cost of a length, l, of the conductor ; and p = percentage allowed for interest on and depreciation in value of conductor.

Then $$\frac{C^2 R}{J_1} P = p\, m. \quad C = \sqrt{\frac{J_1\, p\, m}{R\, P}} \quad (36)$$

Now as R and M are both proportional to the length, a calculation for one length will apply to any other. M can be taken directly from the manufacturer's price list, R can be obtained in the same way or calculated, p can be assumed according to the judgment of the engineer for any locality, and P calculated for the same place.

P will vary with cost of motive power, labour, system employed, number of hours during which plant is run per year, and other circumstances, and will have to be calculated by the engineer putting in a plant.

Discussions on this subject and on the safe currents for various wires have been given by a number of persons, notably, Prof. Forbes, Mr. Preece, Mr. W. Geipel and Mr. T. H. Blakesley. Tables also have been prepared by several of these gentlemen ; but they have been principally for bare wires, and the safe currents have been calculated on the assumption that the absolute emissive power for different wires of the same material is constant. When this paper was begun it was hoped that sufficient data could be obtained for calculating tables which would include, besides the resistance, fall of potential per unit length, and economical current, the safe current for each size of bare wire and of wires covered with the most common insulations. It is now evident that more extensive experiments than time permitted of making must be completed before the safe current can be computed for all wires. Tables, giving much of the other data have been computed ; although the cost of the insulation would make a difference in the economical currents for insulated wires. It is hoped that at some future time the necessary experiments may be made and these tables made out.

Physical Laboratory of the Cornell
University, *June*, 1885.

NEW ZEALAND TELEGRAPHS.

In the supplement to the *Australian Times and Anglo-New-Zealander* of the 5th inst., we notice a correspondence of high interest to the Eastern Extension Telegraph Company. This correspondence is between Mr. Pender, as chairman of this company, and Sir Julius Vogel, the Premier and Postmaster-General of the New Zealand Government. In a telegram dated the 31st March of the present year, Mr. Pender's usual ability seems to have forsaken him, for he says to the Postmaster-General of New Zealand amongst other matter of small consequence to others, "You negotiated and arranged the terms for present cable between New Zealand and Australia and know why the cost was so much in excess of what the cable could be laid for to-day." Mr. Pender's telegram of 31st March probably arrived in New Zealand on "All fool's day," and the Postmaster-General should have taken the telegram as a slight joke on Mr. Pender's part; but no, on the 2nd of April he indignantly replies through Mr. Secretary Gray, "In reference to your telegram of the 31st ult., the Postmaster-General wishes to say that he does not know why the cost of the cable was, as you state, so much in excess of what the cable could be laid for to-day and he would be glad of an explanation of the cause to which you refer." Mr. Pender then replied he had nothing further to add but that the Postmaster-General having negotiated the contract was as well acquainted with the details as Mr. Pender. Experience should have taught Mr. Pender that "*on ne badine pas avec l'amour.*" This is the less excusable in a man who at each general meeting of his telegraph companies assures his people that "our relations with foreign Governments are in a very satisfactory condition," *vide* Queen's Speech and the Eastern Company's reports and addresses to shareholders. New Zealand, in what we may call the "Eastern Question" of telegraphy, seems to have been treated too much on the same lines as Bulgaria; the paragraph we print elsewhere gives the true story of the battle. Place Sir Julius Vogel in the position of Prince Alexander, Mr. Pender in the position of General Kaulbars, the Octopus Eastern Telegraph Ring in the position of Russia, and we understand the whole matter. In the picture before our readers will be missed the European concert, but to make this picture complete this concert can be supplied by the cable manufacturing market. We often have pondered over and vivisected, if we may say so, the sketch given some years ago in our contemporary the *Penny Illustrated*, where the Chairman of the Eastern and other companies was described as the "Napoleon of Telegraphy." We then ventured meekly to suggest that the "Wellington of Telegraphy" might be found in the same ranks. This we now withdraw. General Kaulbars gives us the key note, and the "Kaulbars of Telegraphy" will be accepted by friends and foes alike as a substitute. Be the title what it may, the condition of affairs between the Eastern Extension Company and the New Zealand Government does not appear to be friendly to judge from the supplement in the Australian *Times*, and the address of Mr. Pender to the Eastern Extension shareholders on the 27th ult. In this address Mr. Pender, with some warmth, stated that he will take care that the Eastern Extension Company is not trodden on by the New Zealand Government, and that the directors will insist on maintaining the dignity and position of their company. Mighty words these! and verily, John, we say unto thee that were they backed by honesty of purpose and not by wrath alone, they might avail thee, even at this the eleventh hour.

NOTES.

United States Correspondence.—American readers please notice that the minimum postage on letters to England is 5 cents, and post cards 2 cents. We frequently receive the former with 2 cents, and the latter with 1 cent only, and in consequence are mulcted in payment of double postage on delivery. As this occurs very often we have decided to decline all such insufficiently paid correspondence.

Instituting a Comparison.—The Admiralty, it is stated, is desirous of instituting a comparison between the cost of the work of installing the electric light on H. M. ships as carried out by private firms and that performed by dockyard employès. Until quite recently the bulk of the electrical work in connection with the Royal Navy was performed by contract—always, we believe, with the most satisfactory results; while small electrical staffs at Portsmouth and Devonport were principally engaged in carrying out repairs and minor details. However, a short time since "my Lords" decided to create large electrical staffs at all the dockyards (obtaining novices from the shipwright department as recruits), with the avowed intention of ultimately withdrawing the work of installing the electric light on Government vessels from private firms. A test as to the relative cheapness of the two systems is however now to be instituted, and a tug of war will take place with the view of seeing whether private contractors can fit H.M.S. *Benbow* at Chatham with the electric light more economically than the authorities at Portsmouth can supply H.M.S. *Howe* with the same illuminant. The result of the duel will be awaited with some interest, especially as the dockyard workmen are to use their own materials.

The Electric Light on the ss. "Orinoco."—The latest addition to the Royal Mail Steamship Company's fine fleet, the *Orinoco*, which has been built at Glasgow on the newest and most approved principles, has arrived at Southampton to commence her round of service. The vessel has been fitted throughout with the electric light; Messrs. Siemens Bros. having supplied the necessary fittings and machinery. Two dynamos, each worked by an engine, are in use, being capable together of producing 566 lights of 16 candle-power, which can be turned on and off in the saloons and cabins at pleasure. Electric lighthouses have been erected for the purpose of illuminating the port and starboard sides of the ship, while adjacent to the captain's cabin is a chart-room, containing portable electric lighting apparatus. To provide against the unlikely contingency of a breakdown in the supply of electricity, oil lamps have also been fitted in every part of the ship. Hitherto the heat of the tropics has been intensified on board many steamers by that arising from the lighting apparatus, and no doubt passengers in the *Orinoco* will appreciate the presence of a beautiful light without the accompanying drawbacks of heat and smoke, If the convenience of passengers were consulted as fully as it ought to be, electricity would be adopted for illuminating purposes on every ocean-going steamer.

Church Lighting.—The *Christian Leader* states that Hillhead Baptist Church has the distinction of being the first place of worship in Glasgow lighted by electricity. The new light was introduced on the first Sunday of this month, and was very effective and pleasant. It was judged by all who were there to be in every way a decided improvement upon gas.

The Earl of Shrewsbury, who at the beginning of the present year had the electric light introduced to Ingestre Hall and the adjoining offices, has now had the parish church, which is near the hall, fitted up with the new light. A special service was held on Saturday evening to celebrate the event.

Electric Lighting of Ships.—We understand that the whole of the wire leads, main and branch, used on the *Dalhousie* and *Lawrence* were supplied by the London Electric Wire Company.

Electric Lighting in North Staffordshire.—At Mr, Alfred Meakin's Tunstall manufactory, known as the Albert Works, the first installation of the electric light on a large scale in the district was, according to *Industries*, successfully started a fortnight ago. Mr. W. O. Rooper, C.E., of Stafford, has been the designer, the dynamos being built and the wiring effected by Messrs. Paterson and Cooper, of London. The machinery consists of one diagonal frame double cylinder steam engine, capable of developing 65 H.P., driving, by means of a belt, a Phœnix dynamo, which runs at a speed of 650 revolutions per minute, and can give an output of 30,000 volt ampères. 450 Swan incandescent lamps have been provided within the factory, each room being furnished with a main switch for turning on or off the lamps in that room, and, in most cases, each individual lamp is provided with a separate switch and safety fusible cut-out. Power has been allowed for the lighting of the lower works, which Mr. Meakin is about to add to his factory. Over four miles of wire have already been used, and it is calculated that some three miles more will be required for the lower works.

Electricity v. Gas.—If sufficient funds can be raised by voluntary subscription, it is intended, at Penzance, to fully test the suitability of the electric light for the street lighting of the town, a recommendation to this effect having been made by the committee appointed at the recent public meeting to consider the subject. The expense which must necessarily be entered into if electricity is to be adopted, has rather frightened the Corporation from looking with any degree of kindliness on the scheme, while the chances of floating a company on the lines projected by Mr. Wharton are not considered particularly rosy. A few gas lamps of an improved pattern are to be erected in order that the respective merits of both modes of lighting may be simultaneously judged.

Water Power for Electric Lighting.—It is estimated that up to the present time not less than 14,000 horse-power, derived from river falls, is in use in the United States and Canada, for driving dynamo-electric machines. This power is for the most part employed for electric lights.

Canal Lighting by Electricity.—The canal passing through Douai has, of late, been so encumbered with coal barges as to seriously impede the traffic of that important water way. To avoid the block, *Industries* states, it has been resolved to pass the boats along the canal by night as well as by day, and, with this object, electric lights have been set up along the banks. By this means the traffic has been greatly facilitated.

Electric Lighting on the Brighton Railway.—The London, Brighton, and South Coast Railway Company has given an order to the Railway Electrical Contractors for a considerable extension of the system of lighting railway carriages by electricity, which has been successfully in operation on this line for some years past.

Electric Lighting at the North British and Mercantile Insurance Company's Offices.—The installation at the above premises has now been completed, and consists of a 9 H.P. gas engine driving a 9 unit dynamo which supplies current for charging 53 E.P.S. cells of the 23 L type, the number of lamps fixed being 160. The installation was designed and carried out under the superintendence of Messrs. Drake and Gorham, the late managing engineer and works' manager of the E.P.S. Company, the contractors for the work.

Electric Lighting by Meter in London.—A correspondent writes to us that the firm of Messrs. Hick, Hargreaves & Co., has just completed, in less than a month, a horizontal Corliss valve steam engine of 500 horse-power for driving a Ferranti dynamo machine at an electric lighting station in London, this machine being capable of generating sufficient current to supply 5,000 lamps. The company for which this powerful machinery has been made—and we may here mention that Messrs. Hick, Hargreaves & Co. have also constructed the dynamo—is already furnishing electric light by meter to a large number of private consumers in London, in substantially the same way that gas is supplied through meters by gas companies or corporations. A feature in the construction of the dynamo is the solidity and massiveness of the frame which carries the magnets, this portion of the machine being about twenty tons in weight, and about nine feet in diameter. It is one of the largest dynamo machines—if not, indeed, *the* largest machine—yet turned out. The whole of the castings and forgings were made, machined, fitted together, and erected as a finished engine, complete in every detail, a few days ago, the order being received on the 15th of October. The fact of this additional machinery being urgently required is an interesting illustration of the important progress which the system of electric lighting is making in the metropolis; and we surmise that the Grosvenor Gallery is the destination of the apparatus.

Domestic Electric Lighting.—Electric lighting for private houses has been successfully inaugurated by the E.P.S. Company at Scarborough, where the residence of Colonel Steble, late M.P. for Scarborough, has been lit by means of about 100 lamps, supplied by a 7 unit Elwell-Parker dynamo and 33 cells, 31 L type. The power is supplied by a 7 H.P. gas engine of the latest type. The mode of lighting adopted throughout this installation chiefly consists of pendant lamps suspended in handsome shades at a few inches from the ceiling, with the exception of the hall, billiard-room, &c., for which some elaborate fittings have been supplied. The installation is in charge of a local man, and the whole apparatus has been rendered so simple by Messrs. Drake and Gorham, who designed the installation, that no trouble whatever has occurred in the manipulation of the plant.

An Expensive Mistake.—The West India and Panama Telegraph Company, the *Colonies and India* says, is likely to have an expensive experience of a telegram. It appears that in consequence of some mistake being made in a telegram sent by the R.M. Co.'s agency at Kingston, all the passengers for Havana and Vera Cruz, who should have arrived there in the *Para* for transhipment to the *Dee*, were landed at Barbados, and taken thence to Porto Rico by the *Esk*, where a Spanish steamer was chartered to convey them to Havana. The ship arrived at Havana on October 12th, and the passengers for Vera Cruz were sent to lodgings, awaiting the arrival of the *Dee*. It is said the telegraph company will be called upon to pay all expenses.

A Telegraphic Breakdown.—Some inconvenience was occasioned at Stalbridge a few days since owing to the failure of a new telegraphic instrument on the Templecombe side. The 7.25 a.m. passenger train from Bournemouth was brought to a standstill, and a pilotman had to be sent to Templecombe to accompany the engine. Soon afterwards matters were set right.

The Telegraph Clerks and the Royal Commission.—A crowded meeting of Edinburgh and Leith telegraphists was held on Saturday evening, last week, to decide what steps should be taken to prepare evidence to lay before the Royal Commission recently appointed to enquire into the working and organisation of the Civil Service. It was agreed to assist the Commission by collecting evidence, and representatives were appointed for the purpose.

The Improvement of Telephony.—At the opening meeting for the present session of the Edinburgh Association of Science and Art held on Monday a paper was read by Mr. J. Stevens on telegraphic and telephonic communication.

West African Cables. — The steamer *Silvertown*, belonging to the Silvertown Company, arrived in the Victoria Docks on Sunday, the 14th inst., after a most successful voyage on the West African Coast where she was engaged, in company with the *Dacia* and the *Buccaneer*, in the laying of a series of cables which the Silvertown Company had manufactured for the West African Telegraph Company. The *Silvertown* sailed from London on July 3rd, and has thus been absent about four months and-a-half. During this time she has steamed over 12,000 miles, and returns to Silvertown without consuming the whole of the coal she took on board before starting on her voyage. The expedition just concluded comprised the laying of six cables landing at Grand Bassam, Accra, Kotoonon, or Porto Novo, at Principe, Sao Thomé, Gaboon, and St. Paul de Loanda. The total length of cable laid amounts to about 2,300 nautical miles, and considering the climate and the landing of 12 shore ends through a West African surf, the staff of the Silvertown Company are to be congratulated on the success attending their efforts. The work has been carried out under Mr. Matthew Hamilton Gray, the director of the expedition, ably seconded by Mr. H. Benest, chief telegraph engineer, Mr. A. S. Thomson, commanding the *Silvertown*, Mr. Rymer Jones, chief electrician, Mr. W. A. Tindale, commanding the *Dacia*, Mr. W. S. Seaton, assistant to director, Mr. Stoddart, superintendent engineer, Mr. D. Wilson Barker, commanding the *Buccaneer*, and a staff of about 300 officers and men. During the operations Mr. R. E. Peake, assisted by Mr. Bent, represented Messrs. Clark, Forde and Taylor, the engineers to the West African Telegraph Company.

Another Petroleum Engine.—A new petroleum engine, invented by the electrician, Herr Siegfried Marcus, of Vienna, is being supplied to the German navy for its torpedo boats. It is described as far more powerful than a steam engine of the same size, and less liable to derangement. Several years ago we described the electrical apparatus, devised by Herr Marcus, for exploding the gaseous mixture in the cylinders of such engines.

Incandescent Lamp Leads.—Messrs. Walter T. Glover and Co., of Salford, Manchester, have sent us a sample of a twin flexible suspending wire for incandescent lighting, which is made fire-proof to meet the requirements of the insurance regulations.

Underground Conductors in Lead Pipes. — The durability of lead pipes is a very important question. In Brooklyn the pipe enclosing the Brook's system of conductors shows a corrosion of one-eighth of an inch in depth, and the indications are that the whole pipe will be consumed. Professor Plympton says the corrosion is caused by the action of water gas, which collects in the ducts. The Western electric underground cables in the same situation have a small percentage of tin in the pipes, for the purpose of stiffening, but it also appears to act as a protective agent to the lead, for no signs of corrosion have been yet discovered. Have any of our readers had any practical experience in these matters?

Electro-Motors in America.—The concluding paragraph of the very interesting paper on the Sprague system on p. 489 is well worth careful study, although it has for some time been a matter of common knowledge that with a given available horse-power ready for distribution at a central station, nearly double that amount may be safely contracted for without the chance that the demand will ever be in excess of the supply.

The Transmission of Power.—We shall watch with great interest the proposed undertaking of the Sprague Company of America to transmit some 200 horse-power 16 miles with 1,000 volts at the motors. So far as experiments on this subject are concerned we have had a surfeit; perhaps the Sprague Company will give us some practical results without the supervision of an academical committee or the financial support of a millionaire.

Legal.—*Re* Huon and Collet.—This was an adjourned meeting for public examination. The bankrupts were opticians and electricians, carrying on business at 52, Hatton Garden. Collet was not in attendance, but Huon passed his examination upon a statement of affairs showing joint liabilities £5,070 11s. 2d., and assets £953 12s. 4d.

An Electrical Clock.—A new system has been adopted at Mount Wise, Devonport, for the purpose of "closing" the ball at the semaphore station which gives the signal for the firing of the well-known "one o'clock gun." Messrs. Dent, of the Strand, London, have supplied an electric clock for which a house has been built in the fort, and electric wires connect it with the ball, which must then fall at the precise moment. The new departure will prove a great advantage to the mercantile marine and to the ships of the Royal Navy. In case a ship arriving wishes to be informed as to the correct Greenwich time she will be able to signalise Mount Wise, where the ball will be opened in such a manner as to indicate a correct reply.

Transmission of Power.—The New York *Electrical Review* gives the following estimate of the cost and profit of a power station:—160 horse-power boilers, 140 horse-power in engines, two dynamos capable of generating current equivalent to 100,000 watts, wires, &c., $17,000; 280 horse-power may be sold, as is shown by experience of those renting steam power. There is no expense for motors, as each user owns his own. Income from rental of power, $125 × 280 = $35,000; running expenses, $8,000; profit, $27,000, or more than 150 per cent. on cost of plant. If the station furnishes current for lighting purposes during the evening, the percentage of profit could be largely increased. Burning cheap fuel under the best conditions, $15 can be made to buy enough coal for one horse-power per year.

The Sanitary Institute Exhibition at York.—The report of the judges of this exhibition announces the following awards to the Woodhouse and Rawson Electric Supply Company of Great Britain:—Medal for Cunynghame's magnetic cut-out for electric lighting; special certificate for incandescent lamps; certificate of merit for combination plug and metre-bridge.

Electro-Metallurgy.—It is intended to exhibit in Section III. of the Manchester Jubilee Exhibition the historical and modern methods adopted in the several branches of electro-metallurgy, such as gold, silver, platinum, nickel and copper plating, the purification of metals by electrolysis, and generally to illustrate the connection between electricity and chemistry. Applications for space should be made not later than December 1st.

Society of Arts.—In addition to the announcements made last week, we understand that Mr. Edward H. Liveing will read a paper before the society on "Miners' Safety Lamps." The fourth course of Cantor lectures will be given by Prof. W. C. Unwin on "Machines for Testing Materials, especially Iron and Steel."

The Saltaire Exhibition.—The directors of the Yorkshire International Exhibition at Saltaire have decided, in consequence of numerous requests from exhibitors who have not yet completed their arrangements, to extend the time during which applications for space can be sent in to the 1st proximo.

Dynamo Construction.—Our readers will do well to ponder over the first paragraph of the paper by Drs. J. and E. Hopkinson on p. 489 of our present issue. The effect of commutating the sections of an armature s very forcibly expressed.

Why the Compass Went Wrong.—The *Orizaba* is a new steamer. The compasses are Sir William Thomson's patent. When swinging the ship, the reading of the bearings by one of the officers, the *Scientific American* states, was always different from that by other officers. This led to a wordy contention, the officer maintaining that his reading was correct. The difference was at last discovered to be due to that officer having on a steel truss. These compasses are so sensitive that they are affected by such very minute disturbing influences. The officer had to go on shore and provide himself with a truss constructed free of iron.

The Telegraph Service.—On the occasion of the recent visit of Lord Randolph Churchill to Bradford, separate verbatim reports, amounting to the total of 270,000 words were telegraphed by the Post Office. Fourteen Wheatstone sets of apparatus, and additional battery power, representing an E.M.F. of 640 volts, were brought into use, and direct communication was established with the most distant towns in the kingdom, including Aberdeen, Dundee, Cardiff, Bristol, &c. That a provincial station that does not ordinarily deal with very great quantities of press work should be able to dispose of as much matter in the few hours of an evening as would fill 100 columns of a daily paper is very good evidence of the capabilities of the Wheatstone transmitter, and of the efficiency of the postal telegraph service.

Honours.—The Senate of the Royal University of Ireland has conferred the honorary degree of D.Sc. upon Prof. John Perry, F.R.S.

Electrically Propelled Boats.—*The Admiralty and Horse Guards Gazette* for November 13th contains an article upon this subject, in which it deals principally with the achievements of the *Volta*. Our contemporary believes that the time has arrived when the Admiralty should put this novel and highly useful invention to the test.

Wonders will never Cease.—Our usually careful contemporary, the *Mechanical World*, last week contained the following amusing paragraph, which is too good to be lost:—"The 'American' dynamo, used for running the lights on the statue of 'Liberty,' at New York, will support 15 lamps of 6,000 candle-power, at 875 revolutions with 30 ampères of current at an electromotive force of 700 volts. The resistance of the machine is $3\frac{1}{2}$ ohms. It weighs 3,700 *volts*. There are 240 lbs. of No. 9 copper wire on the armature and 640 lbs. No. 5 (B. and S.) copper wire on the field magnets The total electrical horse-power in circuit is 52 H.P.; *the horse-power required at the dynamo pulley is* 35 *H.P.*; the electrical horse-power per lamp is 1·53 and the electrical efficiency of the machine is stated to be $91\frac{1}{2}$ per cent."

Silvertown Company.—The cable steamer *International* arrived at the moorings off the Silvertown Works, on Wednesday, the 17th inst., on her return from repairing and renewing in part one of the Havanah Key West cables. On account of the depth of water and the strong currents running along the north coast of Cuba considerable difficulty has been experienced in effecting this repair, which has been successfully carried out by Mr. Theophilus Smith, engineer in charge, Mr. March Webb being chief electrician. Mr. Smith has been greatly aided by the local knowledge of Mr. M. Hellings, the cable manager of the International Ocean Telegraph Company.

The Jablochkoff Company.—We understand that this company is going through another "phase" of its existence, or, more plainly speaking, that changes are being introduced in the managerial department.

Business Prospects.—We hear that Messrs. Paterson and Cooper are very busy both in manufacturing testing instruments and dynamos for this country and the Continent, and, so far as we can learn, things are generally looking hopeful in the domain of electric lighting.

The Incandescent Lamp Monopoly.—Major-General C. E. Webber, Managing Director of the Anglo-American Brush Corporation writes to us as follows :—"With reference to the report in your last issue of the meeting held at Cannon-street Hotel, for the purpose of forming a combination of those interested in the incandescence lamp question, I shall be glad if you will kindly allow me to state that no representative of the Anglo-American Brush Electric Light Corporation was present ; and that I have not given my consent to my nomination as a member of the committee appointed to co-operate with Messrs. Woodhouse and Rawson."

Smoking Concert.—The Electrical Engineering Football Club of 12, Princes Street, Hanover Square, held its first Smoking Concert on Wednesday, 17th inst., at the Mason's Hall Tavern, Basinghall Street. Messrs. A. E. Braddell and G. S. Aspinal presided at the piano. The next concert will be held December 7th.

Electric Sun Lamp Company v. Sir Coutts Lindsay and Company.—In the Queen's Bench Division of the High Court of Justice, on Wednesday, Mr. Fletcher Moulton, Q.C., appealed on behalf of the defendants against an order made in Chambers that the defendants should bring into Court as a condition of their being entitled to defend the action the full sum in dispute between the parties, namely, £766 9s. 8d., which was claimed by the plaintiffs as the price of lamps, dynamos, &c., supplied by them. Mr. Moulton contended that his clients were not liable for the full amount, and that the order was made upon misrepresentation. The contract under which the claim was made was between the plaintiff company and Sir Coutts Lindsay personally, and was for the lighting of the Grosvenor Gallery. Sir Coutts Lindsay and Company were only concerned in the matter from the fact that they agreed to take over from Sir Coutts Lindsay a dynamo at the price at which it was supplied to him by the plaintiffs. For this dynamo they had paid £237 10s., or one-half of the price, and were willing to pay the remaining half. The order was probably granted because the judge in chambers was not made aware of the fact that a portion of the goods supplied only were in the possession of the company, the remainder having been supplied to Sir Coutts Lindsay apart from the company. Mr. Mansell Jones, on behalf of the Electric Sun Lamp Company, appeared to oppose the application, and stated that an attempt had been made to confuse the two parties, Sir Coutts Lindsay and Sir Coutts Lindsay and Company, and that when application for payment was made to the one they were referred to the other. Mr. Fletcher Moulton denied that any confusion had been caused or attempted. The Court granted the appeal, it being understood that the defendants would pay the £237 10s., balance for the dynamos, into Court.

The Society of Telegraph-Engineers and Electricians.—A meeting will be held at the Institution of Civil Engineers, 25, Great George Street, S.W., on Thursday, November 25th, at 8 p.m., when the adjourned discussion on Mr. Gisbert Kapp's paper will be proceeded with. A paper on "Some Experiments on Secondary Cells," will also be read by Mr. James Swinburne, member.

Electro-Chemistry at the Manchester Jubilee Exhibition.—It is intended in Section III. to exhibit the historical and modern methods adopted in the several branches of the art of electro-metallurgy, such as gold, silver, platinum, nickel, and copper plating, the purification of metals by electrolysis, and generally to illustrate the connection between electricity and chemistry. Application for space should be made not later than the first of December.

Domestic Electric Lighting.—The New York *Electrical Engineer*, in a leading article entitled "A new Era in Domestic Electric Lighting," remarks that the results of the attempts which have been made to overcome the difficulties attendant upon central station lighting may be divided into three classes :—First, the Edison three-wire system ; secondly, the storage battery methods ; and thirdly, the inductional transformer. The first plan somewhat diminished the cost of conductors, the second has been but partially successful, whilst the third, our contemporary thinks, is on the eve of being completely successful, and that if this turns out to be the case, the displacement of the existing illuminating gas plants by the incandescent electric system can be at the utmost but a question of a few years time.

An Important Patent.—Messrs. Gaulard and Gibbs have just received a United States Patent for their method of electrical distribution and conversion, with the following broad claims :—1. The hereinbefore described art or method of electrical distribution and conversion, which consists in establishing in a closed electric circuit a current of alternate and equal positive and negative potential, producing by the influence of such current an inductive field of alternate polarity, and thereby inducing in translating devices situated in an independent closed circuit traversing such field a similar alternating secondary current of greater quantity and less potential than the originating or producing current. 2. In a system of electrical distribution, an inductorium or converter, in which the length of that portion of the conductor traversed by the primary current within the magnetic field created by itself exceeds the length within the same field of the conductor traversed by the secondary current, in combination with a dynamo-electric generator producing alternating electric currents or pulsations of equal potential and duration, and translating devices actuated by said secondary current. 3. In a system of electrical distribution, an inductorium or converter, in which the resistance of that portion of the conductor traversed by the primary current within the magnetic field created by itself exceeds the resistance of that portion of the conductor traversed by the secondary current which lies within said field, in combination with a dynamo-electric generator producing alternating currents or pulsations of equal potential and duration, and translating devices actuated by said secondary current. 4. In a system of electrical distribution, a dynamo-electric machine, organized for the production of alternate positive and negative currents, equal to each other in potential and duration, in combination with the primary circuit of an inductorium or converter organised to induce in its secondary circuit alternating currents of lower potential and greater quantity than those of the primary circuit, and one or more translating devices actuated by said secondary currents. 5. In a system of electrical distribution, the combination of an inductorium or converter, having its primary and secondary circuits constantly closed, a dynamo-electric generator for producing alternating currents of equal potential and duration included in said closed primary circuit, and one or more translating devices included in said closed secondary circuit, substantially as set forth.

Electrical Traction.—The Jarman system of tramcar propulsion is somewhat amusingly handled by the London correspondent of *L'Electricien*, M. Berly, who says :—"It is from the *Times* that we extract the technical (?) details concerning the Jarman motor, about which there has been much whispering lately in the electrico-financial world. The characteristic point of the invention consists in an arrangement for preventing excessive heating ; this object is attained by the employment of two armatures, of which one works while the other cools. The motor is actuated by a battery of 60 accumulators placed under the seats (an original idea certainly) ; the whole installation, electrical and mechanical, weighing, for a 46-passenger car, 2½ tons. We shall finish by astonish-

ing our readers when we tell them (we still quote) that the accumulators will be charged at a central station; that those which are exhausted will be removed from the car and replaced by others freshly charged; that the change of direction of motion will be effected by the action of a simple lever (is there any doubt, Oh Stephenson!); and that everything in this invention seems very practical, as far as concerns the model. It is also proposed to light the cars electrically by means of the same current which propels them. When the prospectus of the company (for there must be a company) is in preparation (if it is not already prepared) we advise them to add the engaging paragraph: 'The light furnished by the lamps is brilliant and agreeable.'"

Mr. Holroyd Smith Abroad.—We read the following in the journal *La Loi* of the 29th October, under the heading "Electrical Tramways:" An Englishman, Mr. Smith, has invented a system of electrical tramways which would be, it seems, an improvement upon that which is in operation at the Champs Elysées. Mr. Smith has transferred to one of his countrymen, Mr. Plint, the working of his invention, which is patented, in France. This gentleman has handed over the half of his rights to M. Goujon, a Frenchman. It was arranged that, in consideration of the advances which he would make to Mr. Plint, M. Goujon should have the whole property of the line, the machines, and the materials connected therewith. M. Goujon made the advances, the line was constructed, the inventor sent the machines, and the demonstration took place. It was scarcely finished before Mr. Smith wished to take back the machines and materials; he contends that he only lent them. M. Goujon maintains that he is rightly and duly proprietor, and wants to nominate an arbitrator and have the matter settled.

A Contrast.—M. Berly communicates the following to *L'Electricien*:—"A search which we were making gave us occasion to look over certain specifications, and we could not help noticing the striking contrast between the sobriety of some inventors and the extravagant volubility of others. For example—The Gramme patent for a continuous current machine (No. 1,668, June 9, 1870) contains 114 lines, no drawings, and a single claim. The patent of the same, for an alternating current machine (No. 4,066, October 14, 1878), contains 92 lines of description, one sheet of drawings, and five claims. The Rapieff patent, 'Production and application of electric currents for lighting, &c.,' comprises 2,341 lines (42 pages), 27 sheets of drawings, and 23 claims, and that of the same author (No. 211, January 18, 1879), on the same subject, contains 1,904 lines (34 pages), 6 sheets of drawings, and 20 claims. The comparative success of the inventions protected by these patents being given, it remains to calculate to what inverse degree the modest inventor has the advantage over the prolific one."

The New Zealand Cable Subsidy.—In replying to a Wellington deputation with reference to the cable rates on September 27th, Sir Julius Vogel said, according to the *Colonies and India*, that the Government were determined not to yield in the matter. If the company raised the rates as threatened the Government would enforce the terminal charges. The Government will ask for authority to lay a new cable, and a tender at £170,000 for this work has been received. Another report says that the difficulty with regard to rates is likely to be amicably arranged.

We hear that the Agent-General for New Zealand has been instructed to receive tenders for the laying of a duplicate line from Sydney to Nelson, the Government feeling that it is wiser to subsidise a new line than a cable which is now about eleven years old. This policy is approved of, as it will introduce competition for the New Zealand traffic, and consequently a large reduction of rates for inter-colonial traffic.

NEW COMPANY REGISTERED.

Electric Sewage Utilisation and Improvements, Limited.—Capital £500,000 in £1 shares. Objects: To To adopt an agreement of 13th ult. made with the International Canalisation Company, H. de Grousilliers and Co., of Berlin, and others, for the purchase and development of certain patents and premises therein mentioned, and to carry on the business of electricians in all branches. Signatories (with one share each):—A. E. Woodington, 33, The Chase, Chapham Common; L. Hertz, 19, Cantfield Gardens, West Hampstead; F. Howard, Bromley Common, Kent; G. Smith, 3, Copthall Buildings; F. Grant, 72, Bishopsgate Street Within; W. Kern, 44, Hereford Road, Bayswater; A. Rhys Morgan, Riverhead, Sevenoaks. Registered, without articles of association, on the 15th inst. by Percy B. Gregson, of 3, Copthall Buildings, E.C.

OFFICIAL RETURNS OF ELECTRICAL COMPANIES.

Mexican Gas and Electric Light Company, Limited.—The annual return of this company, made up to the 10th inst., was filed on the 15th inst. The nominal capital is £100,000 in £20 shares, the whole of which have been allotted and are fully paid up.

Fischer Electro-Amalgamator Company, Limited.—The statutory return of this company, made up to 30th November, 1885, was filed on the 12th inst. The nominal capital is £25,000 in £5 shares. Seven shares have been taken up, and upon these the full amount has been received. Registered office 15, Queen Victoria Street.

Electro Metal Extracting, Refining and Plating Company, Limited.—The statutory return of this company, made up to the 5th inst., was filed on the 11th inst. The nominal capital is £50,000 in £1 shares. 26,212 shares have been taken up, and upon 1,212 shares the sum of 15s. has been called, 25,000 shares are considered as fully paid. The total calls paid amount to £966 15s., which sum is inclusive of £57 15s. paid in advance of calls. Registered office, 76, Finsbury Pavement.

F. H. Perry & Co., Limited (Opticians and Electricians).—The registered office of this company is at 36, Victoria Street, Liverpool.

CITY NOTES, REPORTS, MEETINGS, &c.

West India and Panama Telegraph Company, Limited.

THE nineteenth ordinary general meeting of this company was held at Winchester House, Old Broad Street, on Wednesday, Mr. C. W. Earle, chairman, presiding. The report of the directors which was submitted to the meeting appeared in the last issue of the REVIEW.

Mr. R. T. Brown, the secretary, having read the notice convening the meeting,

The Chairman, in moving the adoption of the report, said that when last they met to discuss their affairs he stated that they were suffering under the influence of declining traffics. That depressing influence had not passed away, and anyone who watched the sugar market would see the reason. Sugar in the first year or so of the decade during which this company had been in existence averaged from 20s. to 21s. per cwt.; it was now selling at 11s. per cwt., and at the time of the last meeting the average price was 13s., so that there was a decline from what might be called the normal price of the sugar produced in the West Indies of very nearly 50 per cent. since the days when the company was rather more prosperous than it was now. Not only had the West Indian Colonies suffered that great fall in their principal product, but some of them had been visited during the last summer by convulsions of nature which had had a very disastrous effect upon them. Jamaica had twice been swept by hurricanes and great destruction had been caused there; and St. Vincent was visited by a tornado on Augugt 16th last, and, in the words of the Governor in his address to the Legislative Council, it was impossible for any one who witnessed its devastating effects to forget it. This disaster at St. Vincent, coming upon a long period of depression in the sugar trade had forced the Council to reconsider their budget, and he (the chairman)

was sorry to say that they had received a telegram two days ago announcing that one of the reductions made was in this company's subsidy, which was reduced, temporarily he hoped, although the telegram did not say, from £800 to £400 a year. Until they received further details from the Colonies they would not know how to deal with this reduction. With regard to the company's accounts, the expenditure was almost exactly the same as it usually was as far as it was controlled by the directors. There was a saving of about £1,400 as compared with the corresponding period of the previous year, and that saving arose entirely upon items in Abstract C, which referred to repairs and renewals of cable, and was, therefore, subject to great variations. Last half year the original line between Jamaica and Porto Rico, which they had repaired, became inoperative, and it was decided to grapple for it on both sides of the break and put in a new piece of cable of considerable length, relaying it in shallow water. The water was very deep where the original cable was laid, and it was impossible to recover it. While that operation was being conducted they heard of a break in the Colon cable, and the ship being in communication with Porto Rico was immediately instructed to go to the repair of that cable, which was then rather important as it was earning money; they repaired one break, and then found there was another, upon which the ship had now been for some time engaged. She had recovered the Colon end and had spoken to Colon, but since then they had heard nothing more. It was very satisfactory to find that she lifted that cable twice in considerable depth, and that it appeared, as far as they could hear, to be in good strong condition, although it had been down about 15 years. The debenture debt of £50,000 fell due on December 31st, and the directors intended to propose to the holders of the debentures to extend the term upon an interest of 5 per cent. There was one point in the report which was an element of considerable satisfaction, and that was the abandonment of the proposed Bermuda-Jamaica cable. That would have been, he was afraid, a very injurious cable for this company; it would have brought competition into the midst of their system under a Government guarantee, and it was highly satisfactory to have information from the Secretary of State that the idea was, for the present at all events, abandoned. Jamaica was already connected by three cables, and a strategical cable, such as the proposed cable would have been, would almost certainly be destroyed in time of war. He hoped the Government would save the money and not embark upon such a business at all. The general outlook in the West Indies was not just now very encouraging, but they must hope to participate in the benefits of any change which might take place. It was possible if the sugar industry decayed entirely that the West Indian Colonies might find some other means of cultivating their very fertile soil, and there would be some return of prosperity, both for the Colonies and the West India and Panama Company. He moved, in conclusion, "That the directors' report and accounts to June 30th, 1886, submitted to the meeting be and the same are hereby received and adopted, and that, as recommended by the board, a payment of 8s. per share on account of arrears of dividend on the first preference shares, be and is hereby declared."

Mr. Wm. Ford seconded the resolution.

Mr. Wm. Griffith suggested in reference to cable repairs, that an arrangement similar to that of the Cuba Submarine Company should be entered into, by means of which the contractor undertook to keep the cable in repair for a certain number of years. That relieved the directors of a great amount of anxiety, and increased the security of the company.

Mr. A. Morten, in criticising the policy of the directors, said if the shareholders would refer to the last half-yearly reports, they would find that the total receipts for the Christmas half-year were £38,000; those for the current June half-year were £45,400; the interest on investment, debentures, and that kind of security was £4,100; the total income for the year being therefore £87,500. The total expenses for the half-year to Christmas were £23,000; those for the half-year to June, £26,600; the total for the 12 months, £49,600. Deducting that amount from the income, a net profit was left of £38,000. The current interest on the first preference shares was £20,700; that on the second preference shares, £2,800; or a total interest of £23,500. That would leave a total balance, after payment of interest on first and second preference shares, of £14,500 a year. That would render possible a payment of 3s. per share on the ordinary shares. The reserve fund now stood nominally at £122,800, plus the improved value of the securities in which the reserve was locked up, £5,800. Those securities were worth at the present moment £117,300 and they cost £111,500, so that they had profited on that to the extent of nearly £60,000 The reserve had amounted to at least £129,000, and in the meantime they were replacing their cables out of revenue. They were in a splendid commercial position, but he could not get the directors to recognise the fact; they would not look at it in the proper way. They were in a position to borrow on debentures at 4½ per cent. and pay off the arrears on first and second preference shares, and start on a fair commercial footing. It was perfectly absurd to issue debentures at 5 per cent. when they only got 3 per cent. and 3½ per cent. upon securities. Mr. Morten proceeded to argue that if the company was so poor as the directors seemed to imagine, why did they not forego a portion of their fees? He contended that they were not poor, and that the policy which he advocated would free them from an encumbrance and enable them to pay 3s. per share on the ordinary shares, for a good dividend was being honestly earned.

Mr. Guesdon spoke against any interference with the reserve fund, and supported the directors in their general policy. He criticised their conduct upon details, however, particularly with regard to ship insurance and the issue of stamped proxies in the directors' names.

The Chairman stated that they had reduced the insurance of the ships recently upon the suggestion of Mr. Guesdon, but would again take the matter into consideration.

Sir James Anderson said the insurance was even now not enough to replace the ships.

The Chairman said, with regard to proxies, that the directors paid for them themselves, and had a perfect right to send them to shareholders all over the country. He considered the proxy the policeman of the general meeting.

Mr. Guesdon also suggested that it would be a gracious act on the part of the board to reduce the amount of their fees until the company was in a more prosperous condition. He knew something of the work, and in the Colonies directors worked much harder and for less money than in England.

Mr. Newton congratulated the company upon the increasing vigilance of the shareholders, and said he was glad to hear the remarks of both the previous speakers. Having said so much, he wished to add that he disapproved of Mr. Guesdon's remarks concerning the reserve fund. He could not for the life of him conceive how a man could ignore part of his property, and say that the interest upon that property is not his income. The money they derived from the investments of the reserve fund should go to the credit of their annual revenues. As regards proxies, the directors were perfectly right, in his opinion, in issuing them; but they would be perfectly wrong if they let the company pay for them. He did not think directors would be wise not to have proxies to protect the company from a sudden resolution. He quite agreed that any shareholder was justified in moving a resolution if he thought it necessary to do so, but he should not have it in his power to upset the company.

Mr. Wm. Abbott thought the board could not complain of the tone of the speakers who had addressed the meeting. The general feeling, he thought, was expressed by Mr. Guesdon. Proxies had been alluded to, and the wrecking of companies by surprise. He spoke on this subject with some experience, for he had wrecked this company. He confined his wrecking, however, to the late board, and the present board of directors was the result of the chaos he at the time created. Therefore, it was only right that he should come there that day and express his great satisfaction with the position the company occupied, owing to the exertions of the directors for the appointment of whom he was in a great measure responsible. The proprietor who spoke first alluded to the lamentable position in which the ordinary shares stood. He (Mr. Abbott) quite agreed; it was lamentable. But they had securities which placed them in a splendid position. Someone had spoken of the paltry matter of director's fees. Supposing they cut off one-half of those fees: by the judicious selection of investments which the directors had made, they had earned a cumulative profit of £6,000 or six times the amount which had been called in question.

Mr. Mullins suggested that only a portion of the debentures should be extended, and the others paid off out of the reserve fund.

The Chairman, in answering some of the questions which had been asked, said, with regard to Mr. Griffith's suggestion, that the arrangement made by the Cuba Company was an exceptional one, and applied only to one cable which the company had hired. He very much doubted if they could get a contractor to keep a cable at the other end of the world in repair, and if he did so, he would charge such a price as it would be out of their power to pay. The West India and Panama Company bought its cables, took them out in its own ships, and laid them. Mr. Guesdon suggested the separation in the accounts of the items of subsidies and messages; but there would be disadvantages in that course. With regard to the insurance of ships, they had always gone upon the principle that if they lost a ship they ought to be able to recover the money to replace it. They had reduced the insurance already partly in consequence of Mr. Guesdon's remarks at a previous meeting. With regard to interest on investment, he did not quite see the advantage of the course proposed. Mr. Griffiths, the auditor, advised them as to the manner in which to present their accounts, and it seemed to him (the Chairman) that the matter was pretty clearly stated.

The resolution was then put and carried, one shareholder only dissenting.

Mr. Morten then moved: "That inasmuch as this company is possessed of investments to the value of about £117,000, returning under 4 per cent. interest, this meeting strongly recommends to the directors that the present debentures of £50,000 be not extended at the rate of 5 per cent., and that the directors be earnestly requested to take steps to pay off arrears of interest on preference shares, and start the company on a commercial basis."

Mr. Newton seconded the resolution.

Mr. Guesdon moved, as an amendment, that all matters relating to the extending of the debentures and the arrears on preference shares be left in the hands of the board.

Mr. Abbott seconded the amendment, which was carried by a large majority, a vote of thanks to the chairman thereupon terminating the proceedings.

Pilsen-Joel and General Electric Light Company, Limited.—An extraordinary general meeting of this company was held at the Cannon Street Hotel on Wednesday, under the presidency of Sir Rawson W. Rawson, K.C.M.G., when the resolution

passed at the meeting held on Tuesday, the 2nd inst., and reported in our issue of the 5th inst., was confirmed.

London Platino-Brazilian Telegraph Company, Limited.—An interim dividend of 2s. per share will be paid on and after the 22nd inst.

TRAFFIC RECEIPTS.

The Western and Brazilian Telegraph Company, Limited. The receipts for the week ending November 12th were £3,433 after deducting the fifth of the gross receipts payable to the London Platino-Brazilian Telegraph Company, Limited.

PROCEEDINGS OF SOCIETIES.

The Society of Telegraph-Engineers and Electricians.

AN ordinary general meeting of this society was held on Thursday, November 11th, Professor D. HUGHES, F.R.S., president, in the chair. The minutes of the last ordinary general meeting having been read and confirmed, and the list of new and proposed new members announced, a paper was read by Mr. GISBERT KAPP, Associate, on "The pre-determination of the characteristics of dynamos."

If we know the number of magnetic lines of force which pass through the cross section of the armature core at the neutral points, the internal electromotive force developed can easily be calculated from the winding and the speed. Adopting, for convenience of calculation, as a unit line that which is equivalent to 6,000 lines in the C.G.S. system of measurement, we have

$$E_a = z_1 N t n 10^{-6},$$

where E_a is the E.M.F. developed, z_1 the number of unit lines passing through both neutral sections, $N t$ the number of conductors counted all round the armature, and n the speed in revolutions per minute. This formula applies equally to cylinder, disc, and drum armatures, but in the former two types $N t$ represents the number of complete convolutions on the armature, whilst in the latter it represents twice that number. The formula also applies equally to bipolar and multipolar machines, the only difference being that in the latter cases the neutral sections to be considered are not diametrically opposite.

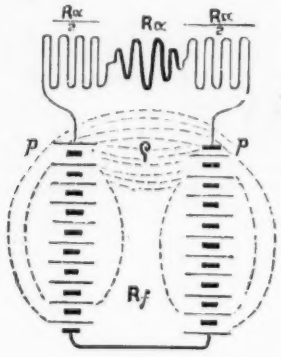


FIG. 1.

The question to find the E.M.F. of a given armature therefore resolves itself into the determination of z_1, the number of lines passing through the armature core; and in the following I would submit a suggestion for the solution of this problem, if the constructive details of the machine, the exciting power, and the quality of iron are known. Stated in other words, the problem is to construct the characteristic curve of a dynamo from its drawing without having recourse to experiment.

Since the usual characteristic representing the relation between exciting current and electromotive force depends on the speed, it is more convenient to use the characteristic of magnetisation, where abscissæ represent exciting power and ordinates the number of useful lines. As far as I am aware, the only attempt to represent the relation between these quantities mathematically is the ingenious and very simple formula by Fröhlich, which has been further developed by Professor Silvanus Thompson. According to the original notation of Fröhlich the effective magnetism (M) is represented by

$$M = \frac{i}{a + b\,i},$$

where i is the current of a series-wound dynamo (therefore proportional to the exciting power), and a and b are constants to be determined experimentally for each machine. For an infinite current the magnets become saturated, and the effective magnetism equals $\frac{1}{b}$. If now absolute saturation be considered as unity, and actual magnetisation be expressed in reference to it, the formula is further simplified to

$$M = \frac{i}{a + i}.$$

In this case the constants to be determined experimentally are a and the E.M.F. corresponding to saturation. In Professor Thompson's well-known modification of this formula, $M = \frac{G\kappa S\,i}{1 + \sigma S\,i}$; there are also two constants which require experimental determination—G, the geometrical constant depending on the configuration of the machine, and the saturation coefficient σ, "which is the reciprocal of that number of ampère turns that will bring the magnet up to such a degree of saturation that its susceptibility is halved."

Now, this necessity of making at least two experiments in order to determine the value of the constants in each particular machine limits the use of either formula to such cases where the new machine differs from that experimented upon in the winding only, but not in size or type. There is another drawback: Fröhlich himself says that his formula only gives correct results if used between limits for which his "curve of current" can be considered as a straight line, and, generally speaking, it will therefore not be possible to construct the whole of the characteristic of magnetisation, even if we have made the necessary experiments for the determination of the constants.

It was with a view to do away with preliminary experiments of the nature alluded to that about two years ago I began to make use of a formula by which the strength of field could be determined from the electrical, magnetic, and mechanical data for each design of dynamo. This formula is based on the conception of magnetic resistance—a quantity proportional to the ratio of length divided by area, and in so far analogous to electrical resistance, but differing from the latter in this respect, that the coefficient with which the ratio of length to area must be multiplied (the specific resistance) is not a constant, but varies with the density of lines flowing through the iron, and reaches infinity at absolute saturation. As regards air or non-magnetic metals this coefficient is, however, assumed to be a constant. The formula, as published by me in a paper read last year before the Institution of Civil Engineers, is

$$z_1 = \frac{P}{R_a + R_a + R_f},$$

where P is the exciting power in ampère turns applied to the horse-shoe magnet which produces the lines z_1 and R_a, R_a, R_f, are the magnetic resistances of air space, armature, and field magnet respectively. The resistance of air space is found by multiplying twice the interpolar distance given in inches (twice, because the lines must leap into *and* out of the armature) with the constant 1,440, and dividing the product by the polar area. In this case the numeric 1,440 is the specific magnetic resistance of air in the arbitrary system of measurement we have adopted. The other two resistances are for very low degrees of magnetisation, found in like manner by determining from the drawing of the dynamo the average distances through which the lines flow in armature and magnet, and dividing by the respective areas; the ratio in each case being multiplied by the numeric 2, which represents the initial specific magnetic resistance of annealed wrought iron. The above empirical formula is only correct for low degrees of magnetisation, and consequently for comparatively weak exciting powers. Assume we have made the calculation and determined the ratio (represented by a straight line) between E_a and P for a given speed. If we now work the dynamo under these conditions, we find that the actual E.M.F. observed is either equal to or slightly higher than the calculated E.M.F., but seldom lower. In other words, the actual initial value of the magnetic resistance is either equal to or slightly less than the calculated value. This is probably due to the neglecting of the influence of edges of pole-pieces, and to errors in estimating the lengths and areas of the flow of lines. Nature finds the easiest way for this flow, and since it is obviously impossible for us in our calculation to hit on a still more easy way, we are likely to obtain (when working with the greatest possible care) a slightly higher resistance. The error is, however, generally very small, and is of no influence on that part of the curve which is of practical importance.

Before entering into the question of how this part of the curve can be obtained, it will perhaps be best to illustrate by analogy to the voltaic circuit the conception on which the formulæ to be given are based. Let, in fig. 1, R_a represent a certain resistance (corresponding to the magnetic resistance of the armature core), connected by resistances $\frac{R_a}{2}$ (representing the two air spaces) with the poles (p, p_1) of a voltaic battery having a resistance R_f (corresponding to the field magnet) and an internal electromotive force P (exciting power).

Imagine at first the apparatus well insulated, then the current z_1 is given by the ratio of P and the sum $(R_a + R_a + R_f)$.

If now the battery be submerged into a badly-conducting medium, currents will flow as shown by the dotted lines, and consequently through certain cells a current flows which is larger than the useful current in R_a. It is impossible to say exactly in what manner these currents of leakage are distributed, but it is evident that the most serious loss must occur between the poles, where the difference of potential is a maximum, and that in a given medium and arrangement of battery the total loss through leakage can be considered as approximately proportional to the difference of potential between the poles. Let the latter have the value p_1, then the current lost, ζ, equals p_1/ρ, if by ρ we

represent the average resistance of the surrounding medium for this particular configuration of battery. We can also, with fair approximation, put the current in the battery—

$$z_2 = z_1 + \zeta.$$

Now imagine that by some means we can give to the electromotive force (E) of the battery any value between zero and that value which will produce the maximum current (z_1) required. It will then be possible to determine what electromotive force is required for each value of z_1, between zero and maximum. To do this we proceed as follows:—We determine first the difference of potential at the poles—

$$p_1 = (R_a + R_{el})\, z_1 \qquad (1)$$

then the loss by leakage—

$$\zeta = \frac{p_1}{\rho} \qquad (2)$$

then the total current—

$$z_2 = z_1 + \zeta \qquad (3)$$

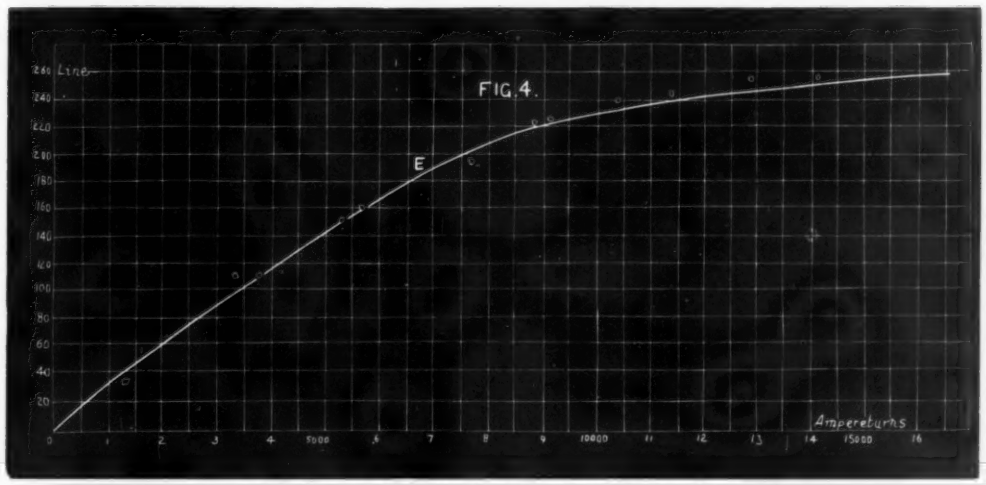
then the loss of electromotive force (p_2) occasioned by the internal resistance of the battery—

$$p_2 = R_i\, z_2 \qquad (4)$$

and, finally, the total E.M.F.—

$$E = p_1 + p_2 \qquad (5)$$

The submerged battery is analogous to a horse-shoe magnet, since the latter is always surrounded by a medium which allows the passage of magnetic lines. To the electromotive force of the battery corresponds the total exciting power applied to the magnet; to the currents z_2, z_1, and ζ correspond numbers of lines respectively created within the magnet core, passing through the armature, and lost by leakage; the analogy of resistances has already been mentioned.



E. Double magnet "Crompton" lines through one half of armature.

Since for small degrees of magnetisation the resistance of armature and magnet are not very different from their lowest initial values, which are very small in comparison with the resistance of leakage, it follows that for the early stages of magnetisation leakage has very little influence on the exciting power; in other words, that the creation of leakage or waste field does not materially increase the expenditure of energy required to produce the useful field. For a more intense magnetisation, such as found in the usual working conditions of dynamos, the case is, however, very different. In the first place, the resistance of the armature has now considerably increased, and with it has increased at a still faster ratio p_1, that portion of the exciting power (or magnetic pressure at the field-poles, if I may be allowed to use a somewhat unscientific term) which is necessary to force the lines through air space and armature. The immediate result is a large increase of the waste field, which has to be provided for by the magnet; augmenting, therefore, the density of lines in the case of the latter considerably beyond the value which would otherwise correspond to the useful field. Hence large increase of magnetic resistance, and consequently also of exciting power. This fact—that the number of lines created must be sensibly greater than the number utilised—explains at once the necessity of making the area of the magnet core considerably larger than that of the armature core. If, with a view to get an equal density of useful lines in armature and field, and thus save weight, the cross section of the magnet be reduced to that of the armature, it will be found absolutely impossible to saturate the latter, no matter how much exciting power we put on. A machine so constructed would therefore be a failure, not only on account of lower voltage, but also because it could not be compounded. Dynamo makers have long ago found out by practical experience that to produce machines of high voltage as compared to the length of wire on the armature, and machines that by reason of their rising characteristics can satisfactorily be compounded, it is necessary to work with a high magnetic density in the armature and a low density in the field. Roughly speaking, if we only take the useful lines into consideration, the ratio is from ·5 to ·6.

Before the formulæ (1 to 5) can be used for the actual determination of total exciting power as a function of the number of useful lines in any given dynamo, it is necessary to make an assumption regarding the rise of magnetic resistance with increasing density of lines. Whatever may be the mathematical connection between these two quantities, it must be of such a nature that for low densities the rise of resistance is insignificant; whilst for a certain and definite maximum density, the exact value of which depends on the nature of the iron, this rise is infinity. Amongst the formulæ which might be devised to fulfil these conditions two fairly simple expressions naturally suggest themselves—the one where the increase of resistance is made proportional to the reciprocal of the difference between saturation density, and working density, and the other where it is made proportional to the tangent of an arc which represents the degree of saturation to such a measure that 90° corresponds to absolute saturation. The value of either of these two assumptions, or of any other which might be suggested, cannot be argued out on theoretical considerations, as we know as yet too little of the laws of electromagnets. The only way is to apply either theory to machines actually tested, and then see which fits in best with practical results. In this way I have found the tangent formula to give better results than the other, and to fit actual experiments with sufficient accuracy for practical work. Without pretending to give a scientific reason why this formula should be better than any other, it might be pointed out as at least plausible that a tangent function might enter into the relation between exciting power and magnetisation. If we assume the act of magnetisation to consist in the bringing of molecular magnets into approximate parallelism with the lines of force passing through the metal, whilst the force resisting magnetisation—which might be a passive one of molecular friction or an active one of inter-molecular attraction or repulsion—tends to turn the molecular magnets away from that position, we can consider each molecular magnet as the needle of a tangent galvanometer having a field of its own and a zero position which may possibly be different from that of its neighbours. Whatever the configuration of these molecular magnets may be, it is at least conceivable that the average angle through which they have been rotated is equal to that of a molecule which started from a position at right angles to the direction of the magnetising force, and that therefore the tangent of this angle is a measure for the current, or, rather, for the exciting power surrounding the core. The weak point of this theory is that it does not show why the angle of rotation should be proportional to the number of lines created, and therefore I do not put it forward as a true, but simply as a possible, explanation.

Whether true or not, the fact of practical importance is that we can by the use of a tangent function determine the increase of magnetic resistance at various stages of saturation in such a way as to accord with experiment, and that therefore the same formulæ can be used for the construction of characteristics of new machines. The only data (besides those taken from the drawing) which we require to know are:—

1st. z_1, the maximum number of lines which can with an unlimited magnetising power be forced through the armature core.

2nd. z_2, the maximum number of lines which can be similarly forced through the magnet core.

These are figures which depend on the dimensions of the cores and the quality of the iron, and if we could rely upon obtaining always the same iron, a few experiments made once for all would

suffice for all future machines. Let the degree of saturation in armature and magnet be denoted respectively by σ_1 and σ_2, so that

$$\sigma_1 = \frac{z_1}{z_1},$$

$$\sigma_2 = \frac{z_2}{z_2};$$

then the actual resistance in the armature core is obtained by multiplying the initial resistance by

$$\frac{\text{tang.}\left(\frac{\pi}{2}\sigma_1\right)}{\frac{\pi}{2}\sigma_1}$$

and similarly for the field magnet.

From numerous experiments made with my own machines, and from data kindly supplied by some other dynamo makers, I am enabled to give the following average figures for the density of saturation to be taken as a basis when using my formulæ * :—

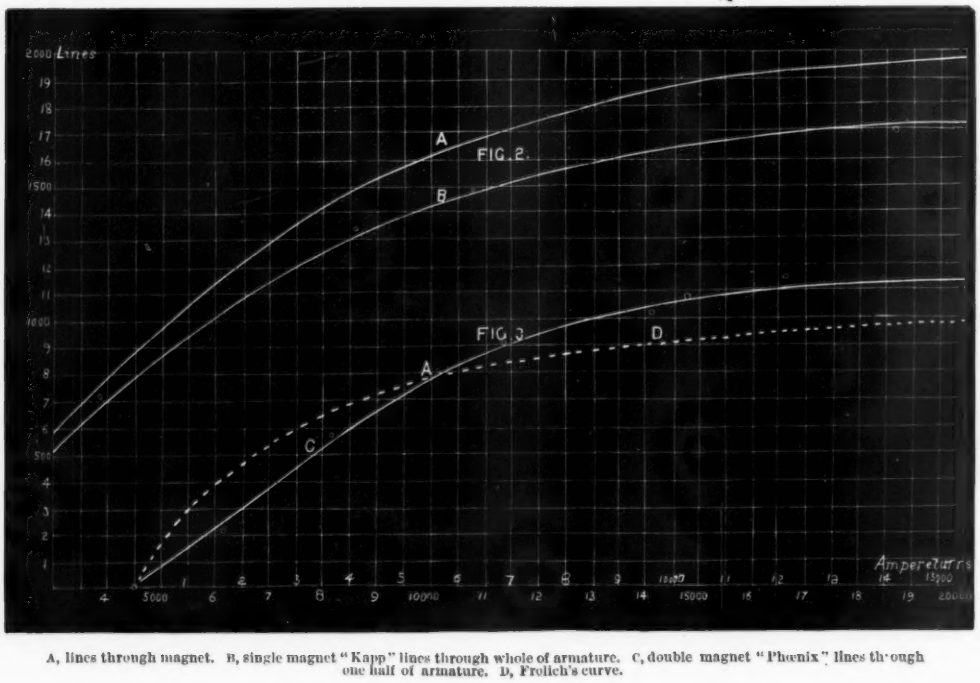
	Lines per square inch.
Armatures—charcoal iron wire well annealed ...	25
,, ,, ,, discs ,, ...	22
Field magnets—hammered scrap ,, ...	18

The superiority of wire over discs is possibly due to better annealing, but probably to the fact that in wire cores the lines run mostly in the direction of the fibres, whilst in disc cores they run as often across the fibre as with it. The inferiority of field magnet iron as compared to armature iron is probably due to the difficulty of thoroughly annealing large masses. I have no records of experiments made with machines having field-magnets composed of thin laminæ. Perhaps some of the members present can give their experience on this very important point. It will be noticed that the figures here given, although by no means the highest which can be obtained with exceptionally good iron, are considerably higher than the maximum induction obtained by the important experiments made independently by Rowland, Bosanquet, and Hopkinson.

The only explanation which suggests itself to me is that the samples experimented on by those scientists were not so good as the usual commercial iron now obtainable for dynamos. Suppose, then, that we know the quality of our iron and its density of saturation. This gives us the values of z_1 and z_2. We now proceed as follows :—We assume a certain number of useful lines (z_1), and calculate the corresponding density (σ_1) in the armature core. The corresponding value of the function $\text{tang.}\left(\frac{\pi}{2}\sigma_1\right) \Big/ \frac{\pi}{2}\sigma_1$ (taken from a table prepared beforehand) is then multiplied with the initial resistance of the armature core (R_a), and added to the air resistance. The sum is multiplied with z_1, and thus we obtain p_1, the quantity which above was called the magnetic pressure between the pole-pieces. The leakage of lines takes place under this pressure, and to obtain the exact number of the waste lines we must know the resistance of the space surrounding the machine. This resistance cannot be calculated in the same manner as that of the air space—so much depends on the configuration of the magnets on neighbouring portions of the iron bed-plate, bearings, &c.; but from the character of the resistance of a non-magnetic medium it is evident that for similar types of dynamos the value of ρ is inversely proportional to the linear dimensions of the machine, Thus this resistance can be found by dividing a constant by the diameter of the armature. An experiment made once for all is sufficient to determine this constant for all sizes of a given type. Knowing ρ, we find the waste field $\zeta = \frac{p_1}{\rho}$, and the total number of lines created $z_2 = z_1 + \zeta$. The ratio of z_2 to z_2 gives us the density in the magnet σ_2, and by again referring to the table we find the corresponding value of the function $\text{tang.}\left(\frac{\pi}{2}\sigma_2\right) \Big/ \frac{\pi}{2}\sigma_2$, with which the initial magnet resistance must be multiplied in order to obtain the actual resistance at that particular density. The product of this actual resistance with z_2 gives the exciting power (p_2) necessary for the field magnet alone, and the sum of p_1 and p_2 is the total exciting power (P) necessary to produce z_1 useful lines. In this way we proceed to calculate P for various values of z_1, and, plotting the results in a curve, we obtain the characteristic of magnetisation, by the aid of which all the working conditions of the dynamo can be found. When determining the E.M.F. of the armature whilst a current is passing through it, account must be taken of self induction, which has the effect of apparently lowering the characteristic. As this action does, however, concern more particularly the armature, and not the field magnet, it does not belong to the subject of the present paper. To show the degree of approximation in calculating the exciting power in the manner above described, figs. 2, 3, and 4 have been prepared. These diagrams contain the calculated curves for three different dynamos, whilst the points indicated by little circles are values obtained in actual test of these machines. The lower curve in fig. 2 is the predetermined characteristic of one of my own dynamos. It shows the number of useful lines passing through the whole armature as a function of the exciting power. The upper curve shows the total number of lines created. The ordinates between the two curves represent, therefore, loss by leakage. In order to enable anybody to check the correctness of these and the other curves, the data on which they have been obtained are given in a table below. The experimental points shown by little circles have for this dynamo the following values :—

z_1 =	715	1330	1490	1705
P =	3800	8600	10800	18600

By the courtesy of Messrs. Paterson & Cooper and Messrs. Crompton & Co. I have been able to test these formulæ on their machines, and the result is given in figs. 3 and 4 respectively. The curves shown in full lines are predetermined characteristics showing the number of useful lines flowing through one-half of the armature. (These machines, "Phœnix" and "Crompton," are of the double magnet type.) The experimental points in



A, lines through magnet. B, single magnet "Kapp" lines through whole of armature. C, double magnet "Phœnix" lines through one half of armature. D, Frolich's curve.

* These figures are not to be taken as generally applicable, but simply as averages of the usual qualities of iron now obtainable.

fig. 3, which were kindly supplied to me by Mr. Esson, have the following values:—

$\frac{z_1}{2}$ =	207·5	594	792	910	1030	1070	1130
P =	1604	3840	5660	6900	9620	11240	12100

For purposes of comparison, a curve obtained by Frölich's formula has been added. This dotted curve shows values of $\frac{z_1}{2}$ obtained by using the function $\frac{P}{\alpha + \beta P}$, where α and β are constants which can be determined if two points of the actual characteristic are known. By choosing these two points near to each other a fair degree of approximation between the actual characteristic and Frölich's curve can be obtained, but only on that portion of the curve which lies between the points. Beyond it, on either side, the divergence is considerable. If one of the points is at $P = \infty$ (which would give, according to Frölich's new notation, the value of s as the reciprocal of the maximum magnetisation), the curve ought to be available from the chosen finite point up to saturation. In the diagram the finite point has been chosen at A, where P = 5,500, or about half the maximum exciting power which would be commercially profitable with this machine, since a larger power than 11,000 ampère turns would not produce any material increase of E.M.F. From the tendency of the characteristic, saturation has been assumed at $\frac{z_1}{2}$ = 1150. This gives $\beta = \frac{1}{1150}$ and α = 2·32. The dotted curve is found by using these values, and shows a considerable deviation from the points determined by experiment. By choosing the finite point A higher up the actual characteristic, a somewhat better accord between the latter and Frölich's curve could be obtained, but at the same time the range over which that curve can be used would be shortened.

As regards the curve of the Crompton machine (fig. 4), the experimental points were kindly supplied to me by Mr. Swinburne, and have the following values:—

$\frac{z_1}{2}$ =	27	112	151	161	197	223	221	240	246	258	258
P =	1409	3300 and 3800	5360	5700	7700	8820	9050	10420	11300	12900	14060

The curves were formed by using the following data:—

Table of Constants for the Three Dynamos investigated.

Fig.	z_1	z_2	R_a	R_a	R_f	ρ
2	2200	2200	3·7	0·40	1·18	30
3	1200	1940	4·7	0·57	0·925	18
4	300	460	2·8	1·00	2·77	47

In the discussion which followed the reading of the paper

Mr. W. M. MORDEY: Asked whether it was not necessary, besides the resistance of the iron in the armature, to consider the magnetising power of the current, because in one part of the armature, at least, that would have a demagnetising effect, and tend to increase the magnetic resistance. Therefore, besides increasing the action of the field magnets, on account of the leakage pointed out by Mr. Kapp, it would probably be advisable to consider the effect of the current.

Professor W. E. AYRTON: Said that the paper possessed especial value inasmuch as it was a continuation of Mr. Kapp's paper read before the Institution of Civil Engineers at the end of last year, and upon which a long discussion took place. Mathematicians might probably fear that Mr. Kapp was endeavouring to substitute a rough and ready calculation for the formulæ they had worked out, but he rather suspected that Mr. Kapp had taken up the problem for the purpose of making better dynamos, and in that respect his work would be extremely valuable. If a practical formula could be worked out which would enable proper calculations to be made of new dynamos of all types much good would be done. He was glad to see that Mr. Kapp had abandoned the value of the coefficient of magnetic induction, given by Professor Rowland, which was not supported by practice. He, and his colleague (Professor Perry), were working at the subject of magnetic resistance when Mr. Kapp first brought out the equation of $z_1 = \frac{P}{R_a + R_a + R_f}$, and they questioned the accuracy of the latter. Investigations were made by them and their results were set out in a paper which was crowded out on the evening when it was set down to be read, and, unfortunately, had not been made public. They felt that Mr. Kapp's formula did not express the actual state of things and that what Mr. Kapp called leakage existed for all degrees of magnetisation, they consequently experimented with an electromagnet 20 inches long, with a soft iron core one inch in diameter, to the ends of which a cube of 1¼ inches of soft iron was fixed. The current flowing was kept constant by means of a reflecting galvanometer, and the magnetic induction, or flow, through the iron was measured by stopping the current and measuring the induced current in a small coil of fine wire through a high resistance galvanometer. The results obtained showed that while the resistance of the 1-inch core was ·5082 the resistance of the air in the armature was about six times as great, or 3·125, when the iron was very far from being saturated. The air always had a resistance, not necessarily always large, but that resistance must not be neglected when the effect of field magnets upon armatures with an air space intervening was calculated; otherwise equations would be erroneous. Armatures of equal size were tried, and also armatures of different shape, and the law of parallel resistance was found to hold good. A curious point was ascertained that the resistances following the natural lines of flow were almost the same as the resistance of the lines of force turned out at right angles, which would show that the old idea of what might be called the natural lines of force was not true. A line of force might have any shape, it depended upon where it came from and was passing to. It would seem that the resistance of an armature, where the lines of force followed each other without any sharp bend, was no greater than the resistance of the line of the armature of the same potential. He hoped that Mr. Kapp would continue his good work, which would be of the greatest possible assistance to makers of dynamo machines.

Mr. J. SWINBURNE said it was very satisfactory indeed to know that Dr. Hopkinson and Mr. Kapp had been independently working at the same subject, and had brought out precisely the same method for working out the characteristics of dynamos; three-fourths of which seemed to be the difficulty in determining the air resistance, which was a very important matter in a dynamo. Makers at present had no difficulty in making similar type machines of enlarged or different dimensions, but they had great difficulty in knowing what a new type of dynamo was likely to do, and that seemed to be the great evil of both systems of working out characteristics. He did not like Frölich's formula, for his first impression of it was that it could not possibly work, that it depended upon certain experiments, and it was to be remembered that experiments could always be made to suit a formula; and when dealing with theories it should not be forgotten that the coefficient of voluntary mendacity was very great. The principal troubles that beset makers of dynamos were the factors of price and ventilation, and they could not be got by any sort of calculation. Mr. Kapp had, he understood, said that machines with too little iron would not compound. It had been Mr. Crompton's practice for some time to put a great deal of iron in his dynamos with very good results. As to the movement of particles of iron, he could not agree with Mr. Kapp, but considered that it was the secant that varied and not the tangent. He promised to work out the idea. Neither could he concur in the opinion as to back, E.M.F., seeing that there would be no continuous current in any one direction, because the current in the armature was stationary. He thought that Mr. Crompton did not laminate with any such notion as that but rather because it was easier to roll bars. The practice of Mr. Crompton was very different to that of Dr. Hopkinson. Mr. Crompton used a great deal more iron in his field magnets than anybody, while Dr. Hopkinson used iron of very little greater cross section than that of the armature. In Dr. Hopkinson's machine, as Professor Ayrton had pointed out, the field magnets became most saturated, while what was wanted was to saturate the armature.

Mr. G. C. FRICKER said that the magnetising power seemed to him to be simply a product of the current and length, and by taking the same length of wire and making two turns of it he could not see how the exciting power, P, could be doubled.

Mr. R. E. CROMPTON could not criticise the paper mathematically but observed that English electrical engineers must feel proud of the papers brought forward by Dr. Hopkinson and Mr. Kapp. In those times, when everything had been kept back in this country by restrictive legislation, and when other countries were having the benefit of the practical results of so much that had been worked out in England, it was a grand thing to be able to put on record results showing that everything had been worked out in this country. Additional point attached to that fact when it was remembered what M. Deprez had lately written. Though not a mathematician his (Mr. Crompton's) eye had taught him a good deal in the way of working out problems, and it had showu him that M. Deprez was wrong; and as that gentleman had obtained the credit of first inventing the characteristic of the dynamo—though really the speaker thought Dr. Hopkinson had done so—and was trying to get the credit of the short stumpy magnets, and of showing the great advantages of reducing the resistances of magnetic circuits, it was very gratifying to hear how everything had been worked out by Dr. Hopkinson and Mr. Kapp. Many present were, no doubt, in the same position as himself, and who could never have built up a dynamo from the abstruse formulæ given in those papers. The question was how the dynamo ever got on; and he could tell them a little history showing that it got on in a much simpler manner than mathematicians would lead them to suppose it had done; and no doubt Mr. Kapp would forgive him for telling stories out of school. Mr. Kapp was at work with him (Mr. Crompton) when the work was carried out, and at that time, though perhaps Dr. Hopkinson was beginning to consider the point, it had not entered into Mr. Kapp's brain, nor into that of M. Deprez, to consider the question of the magnetic resistance of the circuit. He had a very great respect for the Siemens machine, and noticed that it did things that the Bürgin, which he was trying to improve, would not do, and the reason appeared to be due to the enormous mass of metal in the Siemens core which did not exist in the Bürgin machine. Little by little he increased the iron in the Bürgin core, but to get good effect it was necessary to also put a corresponding amount of metal in the magnets, and ultimately a machine with an enormous, in fact ridiculous, quantity of iron, both in the field magnets and in the armature, was produced, and it was that machine which Sir William Thomson said showed extraordinary abnormal activity. Simultaneously Dr. Hopkinson brought out his short stumpy magnets, and immediately every one saw the great advantage of using as much iron with as little air space as possible. Mathematicians since then had greatly assisted in

calculating the best proportions, and the results arrived at had given an enormous impulse to the manufacture of dynamos, by dispensing with copper and putting in iron, which had reduced the price to about one quarter of what it was a few years ago. The results were mainly due to the present understanding of the property of the magnetisation of dynamos. Electrical engineers were in a much more easy position than the ordinary engineers who had to deal with heat engines; because, to use a French word, electricity was more easily and thoroughly "canalised." It could be passed through conductors, and confined to known channels with practically no loss through leakage. But in the armature, and air space, in a dynamo, leakage existed which very much corresponded to the leakage of the heat, and that was very difficult to calculate for. It was the fact, that electricity was so easily canalised that had made electric light calculations such comparatively easy work for students of only a few years standing.

Mr. ALEXANDER SIEMENS drew the attention of mathematicians to the fact that the dynamo machine was not a scientific toy or machine which must be worked to its utmost limits, but should be looked at in the same view as mechanical engineers regarded a steam engine, and who always took the factor of safety into calculation, and made engines capable of much larger work than that which they had actually to do.

Professor G. FORBES and SYLVANUS THOMPSON reserved their remarks for the next meeting.

Mr. W. B. ESSON desired information as to comparative exciting force when discs were used or when iron wire was used; and, given the same section of iron wire and the same section of disc, with the same air space and section of field magnets, what were the data of the comparative excitement in the two cases? Also if the cross section of the field magnets should be very much greater than that of the armature, what ratio should one bear to the other? Very great difference existed in that respect in the machines of various makers. In the Mather and Platt, and Phœnix machines the area of the armature to the field magnets was as 2:3; in the Crompton machine it was smaller than in any other, being exactly half the cross section of the field magnets; and in the Goolden and Trotter machine the cross section of the armature closely approximated that of the field magnets. What was the most economical point in all that variety? He had for some time been working in the opposite direction to that which Mr. Kapp considered the right one, and had been reducing the section of the field magnets, and found an improvement for each diminution of the section of the field magnet core. The unknown quantity seemed to be the leakage, the constant for which could no doubt be used over and over again for different sizes of the same type of machine, but that constant would vary with each kind of machine made.

The PRESIDENT then adjourned the discussion till the next meeting.

NEW PATENTS—1886.

14568. "Electric safety lamps." A. HOWAT. Dated November 11.

14586. "Applying electric motors to ventilating fans, &c." P. HIGGS, E. S. SHELDON. Dated November 11.

14593. "Using accumulators for electrotyping." J. DELLAGANA. Dated November 11.

14595. "Making and breaking electric circuits." T. F. WALKER, J. G. W. FAIRBAIRN. Dated November 11.

14602. "Automatic self-replacing indicator for electric bells." E. R. HEDGMAN, F. VILLIERS-STEAD. Dated November 11.

14673. "Preparing bleaching solutions by electrolysis." E. HERMITE, E. J. PATERSON, C. F. COOPER. Dated November 12.

14696. "Electrical weighing scales." W. R. SMITH. Dated November 12.

14757. "Dynamo electric machine." W. LAHMEYER. Dated November 13.

14760. "Preparing metallic magnesium by electrolysis; solutions therefor." H. H. LAKE. (Communicated by Count R. de Montgelas.) Dated November 13.

14764. "Electrical writing apparatus." F. MITCHELL. Dated November 15.

14765. "Dynamo-electric machines." C. LEVER. Dated November 15.

14823. "Lifting and hauling machinery actuated by electricity." A. G. ADAMS. Dated November 16.

14851. "Electric, incandescent or glow lamp holding apparatus." J. G. W. FAIRBAIRN. Dated November 16.

14867. "Electric switch." J. D. F. ANDREWS. Dated November 16.

14902. "Electric or magnetic motors." G. PRICE. (Communicated by L. Gur and E. D. Fournier.) Dated November 17.

14937. "Preventing the escape of noxious fumes from batteries." M. BAILEY, J. WARNER. Dated November 17.

14942. "Voltmeters." J. S. RAWORTH. Dated November 17.

14943. "Adapting electric light appliances to articles of furniture, internal parts of buildings, &c." C. FERRANTI. Dated November 17.

ABSTRACTS OF PUBLISHED SPECIFICATIONS, 1885.

11707. "Improvements in instruments for controlling electric currents." O. E. WOODHOUSE, and F. L. RAWSON, and J. H. DAVIES. October 1. 8d. Relates to a combination of mechanical devices, whereby the inventors can regulate, control, or cut-out, electric circuits, by extremely small variations in the potential or current of the same or other electric currents. The apparatus consists in an electrically operated contact maker, which by its operation completes either of two electric circuits, and is called a "repulsion regulator." It is used in combination with a "cut out," operated electrically by the primary action of the aforesaid "repulsion regulator," and which, in its various equivalent forms, is called the "controlled cut out." By this arrangement, the comparatively weak force, and consequently exceedingly sensitive action of the "repulsion regulator," is enabled to do work in the control and regulation of powerful currents, by means of the currents which flow through the circuits it completes, and through the subsidiary "controlled cut outs" thereby operated, that it could not effect directly. The aforesaid "repulsion regulator," figs. 1 and 2, consists essentially of one or more solenoids of wire shown diagrammatically by dotted lines, G, G. Within this solenoid or solenoids are one or more pairs of bars of soft iron, A, A, B, B, their length being in the same direction as the axis of the solenoid. One of each pair of bars, A, A, is fixed, and the other in

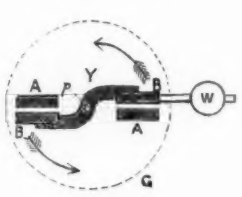


FIG. 1.

each pair, B, B, is pivoted and capable of moving to and from the first fixed bar or bars. The axis of the pivot or pivots, p, may be in the direction of the length of the soft iron bar or bars or transverse to them. The movable bar or bars, B, B, connected together by a yoke piece, Y, rotate on the said pivot, p, placed between or at some distance from the fixed bar or bars, A, A, so that the movable cars, B, B, swing up to the face of the fixed bar or bars, A, A. In this figure the dotted circle, G, represents the coil of the solenoid, and the repulsion of, B, B^1, takes place in the direction indicated by the arrows. In this arrangement, the axis of the pivot, p, is horizontal and the movable bars, B, B, are forced towards the fixed bars, A, A, by a weight, W. Or a spring may be conveniently used if desired for the same purpose, and would be especially applicable where the pivoting axis, p, is vertical. Where the movable bar or bars, B, B, are pivoted transversely to their length, as in fig. 2, the fixed bar or bars, A, A, are cut away at the centre, and bent, and the said movable bar or bars, B, B, are also half jointed by a recess at the centre pivoted by a scissors joint to the said bar or bars, A, A, so that both ends of the movable bar approach to and recede from the ends of the fixed bar or bars. The coil of the solenoid is here shown diagrammatically by a dotted line, G, and the repulsion of the fixed bar or bars takes

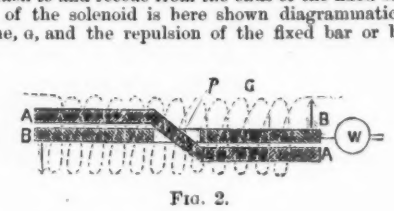


FIG. 2.

place in the direction indicated by the arrows. A counter balance weight, W, is here also conveniently used where the movable bar, B, B, is arranged horizontally, in order to press home the movable bar against the faces of the fixed bar or bars, A, A. The faces of the bars are preferably made flat, so as to lie closely to one another, an electric circuit being completed when the apparatus is home or in normal position by reason of the spring or weight. This is effected by any suitable contact piece on the movable bar being thereby pressed upon a stop or stops. The circuit may be completed through the pivot to one stop, above or below the contact arm, or through the pivot to either of two stops, one above and one below the contact arm; or the contact piece may connect either of two alternative pairs of stops respectively above and below the contact arm. The action of the "repulsion regulator" is as follows:—When a current passes through the coils of the solenoid, G, the soft iron fixed bars, A, A, and the movable bars, B, B, become similarly magnetised to a degree which answers very sensitively to variations in the current passing through the solenoid coils. The movable bar, B, is thus repelled, and, with increasing current, moves away from the fixed poles, A, A, until the contact piece or pieces, C, attached to the former, touches another stop or stops, D^1, and thus completes another circuit. When the circuit to be controlled is in normal condition, the contact arm, C, of the moving magnet bar, B, B, is caused to remain,

by the adjustment of the weight or spring, midway between the contact pieces, D, D¹, in connection with the before-mentioned alternative circuits; but when the current in the coil is above or below its normal value, this contact arm, C, touches one or other of the contact stops, D, D, respectively. The "controlled cut-out" used in combination with the aforesaid "repulsion regulator" consists essentially of an armature, pivoted below its centre of gravity, and placed either vertically between two electro magnets so as to fall alternately towards the pole or poles of one or other of them, according as one or the other magnet is excited; or, it it may equivalently be pivoted on the body or lowêr pole of a single vertical electro magnet. The electro magnet or electro magnets, in either case, are excited by the circuit or circuits completed by the action of the "repulsion regulator." In the first case, the "repulsion regulator" closes two alternative circuits, one at each extreme point of its action, so as to actuate the electro magnet alternately for increase or decrease of potential or current in the circuit. In the second case, the "repulsion regulator" closes the same electro magnet circuit at either extreme point of its action, to operate the "controlled cut-out." The claims are 5 in number.

1886.

8786. "Improvements in dynamo-electrical machines or motors." S. H. TACY. Dated July 5. 6d. The object of this invention is to render dynamo-electrical machines incapable of igniting combustible gases in mines, and to this end it consists broadly in enveloping the commutator and brushes of the machine where practically a continuous spark is produced, with a flame intercepting envelope. This envelope may consist of wire gauze and involve the Davy principle of protection, or be formed of some transparent air-tight material such as glass or mica. Claim:—In combination with the commutator and brushes of a dynamo-electrical machine, or an electrical motor, a flame intercepting envelope, substantially as, and for the purpose specified.

10030. "Improvements in magnetometers for indicating the intensity of magnetism produced by magnets, electro-magnets, or their equivalents." A. MILLAR Dated August 5. 6d. Relates to the instrument described in the number of the REVIEW for September 24th. The claims are 1 in number.

CORRESPONDENCE.

Magnetic Fields.

Under the above heading, I observe in your issue of November 12th that Messrs. Mather and Platt claim priority for an application of short, thick electro-magnets in 1883, to the use of a form of electro-magnet for dynamo machines which a knowledge of the laws of electro-magnetism would appear to point out in many cases as the most suitable and efficient—they would appear to claim priority in the use of short and thick electro-magnets more especially in connection with a Siemens or Edison armature, and they also assert thereby to have "led to entire reconstruction in this respect of all modern types of dynamo machines."

As regards types with armatures not of the Siemens, I should like to point to the short and massive magnets used in the Brush machine, and which have survived, as recently seen in the colossal Brush electro-metallurgical dynamo, to successfully compete with the reconstructed dynamos.

The Bürgin in 1879 also appeared to have had massive field magnets, as also the Heinrichs in 1880.

Of armatures of the Siemens type, the well-known Thomson-Houston appeared in 1880, the armature revolving, it is said, in an intense field; the magnets certainly do not appear to have contained much metal, but the field coils are extremely short and of large diameter.

Lastly, the Weston dynamo machine with Siemens armature, and which was originally built with multiple magnets, as in Edison's machine, appeared in 1882, with double horse-shoe, short and massive magnets, and to which machine with one of its magnets removed, the Edison-Hopkinson of to-day is extremely similar; from the engravings appearing in *Engineering* in 1882 the Weston field magnets appear in length about twice the diameter of the armature, and the aggregate sectional area of the double field appears to be much greater than the cross section of the armature; high character of design is evident from the fact of the perfect self-regulation, though only shunt wound.

No doubt there are other instances of well-proportioned magnets, but this is sufficient to show that the successful results accruing therefrom in dynamo machines were well known before 1883.

G. E. D.

November 17th, 1886.

Welding by Electricity.

In commenting on the above subject in your issue of the 8th ult. I had no desire to depreciate the merits of Prof. Thompson, but only to record what had been done many months ago.

At the time of my communication I was unaware of any patent having been taken out by Prof. Thompson for welding by electricity, neither have I read his specification.

I may not fully comprehend the principle on which his process is based, but it appears to me to depend on increased resistance at a break. When the length of a circuit is invariable, there are two methods by which the resistance (and consequently temperature) is increased at a portion of a conductor, viz., by reducing the sectional area, or by breaking circuit at this point. Breaking circuit may be instantaneous, slow, or continuous to suit one's requirements. Now Professor Thompson does not reduce the sectional area at required junction (except when the article to be welded is of a smaller sectional area than the secondary coil of his apparatus), but to my mind he makes a slow or a continuous break, or a continuous break and reduced sectional area combined.

If Prof. Thompson will kindly read my article again he will perceive that a break is made at the abutting ends of the platinum wires and the other terminal of the dynamo, the filament answering in a very convenient manner as a resistance to, and measure of the current required to fuse the wires. Filaments taking from 1 to 1·5 ampères are generally fastened to platinum wires of about ·0164 inch diameter, not that this size is necessary to carry the required current to render the filament incandescent, but to ensure a stronger lamp, hence my statement that a weld is more easily done with low than with high resistance filaments for the same size of wire.

Anyone trying the operation of welding will become aware of the degree of speed necessary to complete the junction, without either ejecting the fused metal or damaging the glass of the lamp.

J. B. Duncan.

November 10th, 1886.

Secondary Generators or Transformers.

Messrs. Zipernowski and Déri's letter of 30th October shows clearly that they claim as a great and important discovery made by them—the simple connecting of secondary generators in parallel arc.

I am not at all concerned about what the specifications of these gentlemen contain, but I am certainly inclined to maintain my priority of invention as far as parallel arc connection of secondary generators solves the problem of their practical application, and anyone reading the paragraph containing the allusion to my discovery of the fact that secondary generators are self-regulating when coupled in parallel arc, can see that the statement is very decided, and I can prove that it was a statement of facts ascertained by practically working secondary generators in parallel arc.

I had tried Gaulard and Gibbs's system experimentally by connecting in series with constant current and had failed to obtain regulation entirely. I then thought of and tried parallel arc connection and perfectly succeeded in obtaining self-regulation. There certainly is not much visionary about that; the visions of a monopoly I am afraid are all on the other side, and my experiments and published results are likely to somewhat mar the beauty of monopoly visions.

I was not discouraged by the "prodigious" con-

ductors required by such a system, but by the prodigious E.M.F. and conductors combined, and your readers can themselves judge of the "*prodigiousness*" if these gentlemen will only state approximately the section of main conductor required to light up say a district of London, and state the difference of potential between the mains, and remember I used the word three years ago.

Between the date of my first experiments with secondary generators in parallel arc and this date, I have been working at the subject continuously, and have a system which contains a far more important principle than the simple connection in parallel arc, and the last paragraph of Messrs. Zipernowski & Déri's letter shows clearly that the simple parallel arc connection is all that renders their system self-regulating.

I do not know anything about "rational methods of connection of transformer," I know only two methods of connecting to the mains—series and parallel—both of which methods it is open for anybody to apply to any form of transformer.

I am very much alive to the difficulties of such systems of distribution, and am impressed with the important improvements made by these two gentlemen in the dynamos and transformers employed by them, but I am surprised at such a claim as that of simple connection in parallel arc.

Rankin Kennedy, *Electrician.*

November 11*th*, 1886.

Secondary Generators.

We are glad to see a note in your issue of the 12th inst., headed "A New Electric Light," in which you speak of information from Washington of a patent issued to George Westinghouse, jun., of Pittsburg, for a new system of distributing electricity to be used in lighting, and for other purposes.

The system has all the advantages you describe as claimed for it, but we think it right to inform you that the system in question is that of Messrs. Gaulard and Gibbs, to whom the patents in question have been granted, and whose agent in the United States is Mr. George Westinghouse.

Thanking you for the notice in question,

Campbell Reeves and Hooper,
Solicitors to Messrs. Gaulard and Gibbs.

November 16*th*, 1886.

[Further particulars respecting the American patent of Messrs. Gaulard and Gibbs may be found in our "Notes" columns.—EDS. ELEC. REV.]

Insurance Companies and Electric Lighting.

I am glad to notice that the letter written by "Resistance" has been taken up by "Experientia" and Messrs. R. E. Crompton & Co. To my mind, the insurance companies, as a rule, are not strict enough in passing work; and, judging from some that I have seen, I should imagine that they did not even know the places that they insured had the electric light in at all.

There is no doubt that it is high time something was done to put a stop to the jerry and cheap work that is now being put up by many so-called electric light engineers, who are taking the work out of the hands of those that are willing and prefer to work according to such rules as the Phœnix Company. The general public, I presume, are not aware what they are doing, otherwise, I should imagine, it would be better when placing their orders to do so on the conditions that the installations should be carried out strictly on the basis of the Phœnix Company's rules, and to pay Mr. Musgrave Heaphy, or some other well-known firm, to inspect the work. There is no doubt that inferior work will lead ultimately to some serious fires, and thereby retard the general progress of electric lighting business.

H. Bury.

November 17*th*, 1886.

"Let the galled jade wince, my withers are unwrung!" Thus, your correspondents, "Experientia" and Messrs. Crompton; but after very careful reference to my letter appearing in your issue of 5th inst. I am at a loss to discover grounds for the sorrow and surprise which they express. Can they point to any paragraph in my letter which can reasonably bear the construction they appear anxious to apply to all I have said therein, viz., that the fire insurance rules may be dispensed with? Are they unable to see the vast difference that exists between modification and abolition. I do not propose to deny that there is abundance of "*scandalously bad work*" being done, and I have yet to hear of an industry which, not being a monopoly, is exempt from the inevitable consequences of competition; but if your correspondents will reflect over my letter they will see that the object I have in view is not the protection of the so-called electrical engineer whose work would be condemned by any unprejudiced expert, but the giving of a wider discretion to the honest contractor who not only thoroughly understands his business, but whose one aim is to do his best both in the interests of his client and for the sake of his own professional reputation. I again express my opinion that the fire office rules may well be modified and yet leave sufficient restrictive power to meet the case of "*scandalously bad work*" from competition with which your correspondents are no doubt suffering. Mr. Musgrave Heaphy is a courteous gentleman whose acquaintance I enjoy, but this fact in no way prohibits me from criticising the rules which at least he is credited with having compiled, and this criticism is shared by others who condemn "scandalously bad work" as heartily as Mr. Heaphy himself. Strangely enough both your correspondents have, in their anxiety to disclaim anything approaching the second-rate, put the same construction upon my letter while at the same time practically endorsing my opinion that *good* work means *safe* work. May I be permitted to add that the liberality in the matter of conductors ascribed to the firm represented by "Experientia" is to be commended; this is the age of philanthropy, and a system carried out on these lines cannot fail to be a commercial success, *to the client*.

With regard to the P.S. of Messrs. Crompton's letter, I would point out that no reference was made in mine to installations of any particular voltage, nor does the word volt occur therein. I may therefore be pardoned for assuming that to the not too careful reading thereof may be attributed the misconstruction that has been placed upon it.

Resistance.

November 16*th*, 1886.

Dynamo Testing.

With reference to Mr. Trotter's letter in your last, will you allow me space, in the first place, to thank that gentleman for his courtesy, and, in the second place, to say that on reading my first letter on the subject I quite see the limited sense in which the application of the method might be taken.

The fact, however, is that the method was originated for the very purpose of comparing together machines of different types, but I was careful to say nothing about it, first, because the machines were lent by the different makers for the purpose of supplying information to the War Department alone, and, secondly, because I found most makers were strongly averse to the use of their machines as motors.

Perhaps I may mention here that I don't know by what process Mr. Swinburne has arrived at the knowledge that I am not capable of realising the perfection of my own system, *vide* the *Electrician* of 12th inst. It is, however, possibly the same as leads him to infer that three *large* dynamos are necessary for it. In specifying for the supply of dynamos the War Department naturally does not include more tests than it considers necessary and unequivocal.

P. Cardew.